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ARCHIVES OF SURGERY

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COPPER SULFATE METHOD FOR RAPID ESTIMATION OF WHOLE BLOOD REQUIREMENTS

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ST. LOUIS

THIS report is based on a study of severely injured patients admitted to a large general hospital overseas. Of these, 166 had orthopedic injuries of severe degree; 98 others were patients in wards for general surgery. Hemoglobin, hematocrit and plasma protein values were measured before and after surgical treatment, which included particularly the use of large transfusions of whole blood and plasma. The observations indicate that: (*a*) a simple method for measuring hemoconcentration and hemodilution by the copper sulfate specific gravity technic is of great clinical value, (*b*) large amounts of whole blood are needed in the treatment of the severely injured, (*c*) several interesting correlations exist between hematocrit values and changes in plasma protein in these cases.

MATERIAL STUDIED

One hundred and sixty-six patients with severe orthopedic injuries were studied carefully, and for 91 of these detailed records of all fluids and blood transfusions were recorded. Of these, 45 had bad fractures of femur, tibia and/or pelvis; 30 also had injuries of the upper extremity; 6 had fractures through the knee joint; all had some, and the majority had extensive, soft tissue wounds with infection; 4 had penetrating wounds of the chest and 1 had had a nephrectomy and an adrenalectomy on the right side.

SDB

Opinions expressed herein are those of the author only, and do not represent official views of the Medical Department of the United States Army.

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Members of the Surgical Service of the 21st General Hospital rendered valuable assistance in the preparation of this paper. Captain Orens helped in compiling some of the data.

There were also 98 patients on the general surgical wards with soft tissue wounds of the extremity, the abdomen or the chest that required more blood or plasma than the remainder of the patients on general surgical wards. These were selected from a total of 768

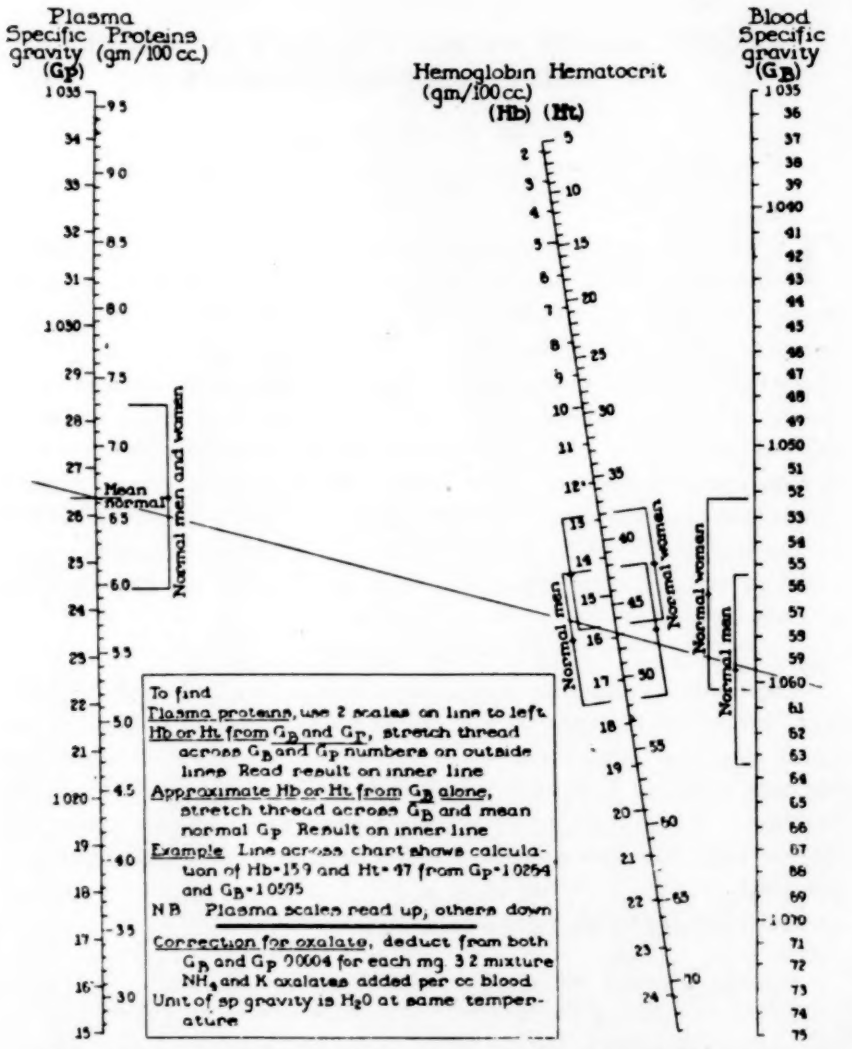
Plasma
Specific gravity (Gp)
Proteins (gm/100 cc.)
Hemoglobin (gm/100 cc) (Hb)
Hematocrit (Ht)
Blood
Specific gravity (GB)
Normal men and women
Mean normal
Normal men
Normal women
Normal women
Normal men
To find
Plasma proteins, use 2 scales on line to left
Hb or Ht from GB and Gp, stretch thread across GB and Gp numbers on outside lines Read result on inner line
Approximate Hb or Ht from GB alone, stretch thread across GB and mean normal Gp Result on inner line
Example Line across chart shows calculation of Hb=15.9 and Ht=47 from Gp=1.0264 and GB=1.0595
N.B. Plasma scales read up, others down
Correction for oxalate, deduct from both GB and Gp .00004 for each mg. 3.2 mixture NH4 and K oxalates added per cc blood
Unit of sp gravity is H2O at same temperature

Chart 1.—Line chart for calculating plasma proteins, hemoglobin and hematocrit values from gravities of plasma and of blood (from Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald [1]).

patients on the general surgical service for whom copper sulfate determinations of hematocrit values, total proteins and hemoglobin were made during a period in the Italian campaign.

Most of the patients had received emergency care and débridement at field or evacuation hospitals; a few, during the Anzio and Cassino offensives, were received directly from battalion aid stations within four to eight hours after injury. In general, however, the periods

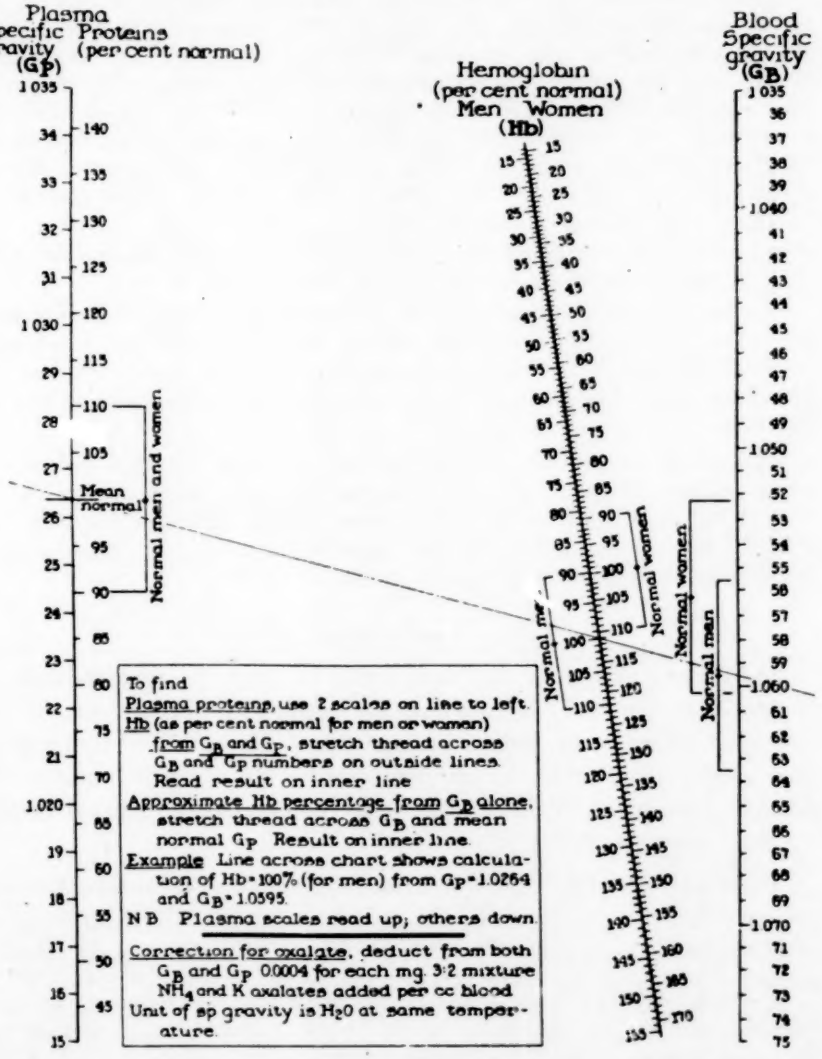
Plasma
Specific gravity (Gp)
Proteins (per cent normal)
Hemoglobin
(per cent normal)
Men Women
(Hb)
Blood
Specific gravity
(GB)
Mean normal
Normal men and women
Normal women
Normal men
To find
Plasma proteins, use 2 scales on line to left.
Hb (as per cent normal for men or woman)
from GB and GP, stretch thread across GB and GP numbers on outside lines.
Read result on inner line
Approximate Hb percentage from GB alone, stretch thread across GB and mean normal GP. Result on inner line.
Example Line across chart shows calculation of Hb=100% (for men) from GP=1.0264 and GB=1.0595.
N B Plasma scales read up; others down.
Correction for oxalate, deduct from both GB and GP 0.0004 for each mg. 3:2 mixture NH4 and K oxalates added per cc blood.
Unit of sp gravity is H2O at same temperature.

Chart 2.—Line chart for calculating percentages of normal plasma proteins and hemoglobin from gravities of plasma and of blood (from Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald [1]).

elapsing between injury and admission varied from one to sixty-one days; 27 per cent of the patients were received within the first four days and 65 per cent within ten days of injury.

METHODS

The use of solutions of copper sulfate of varying but known specific gravities into which a drop of freshly drawn or oxalated whole blood is dropped from a needle enables one to calculate quickly and accurately from a line chart the hematocrit or hemoglobin values and from the plasma the total proteins of the sample.[1] A set of 4 ounce (120 cc.) bottles containing copper sulfate solutions the specific gravities of which vary from 1.021 to 1.070 is prepared.[1a] At the bedside or the operating table, a drop of venous blood may be dropped into the solution directly from the syringe. For whole blood the normal range of specific gravities is around 1.056 to 1.063 for men and 1.052 to 1.060 for women. For less urgent cases, heparinized or oxalated whole blood may be used for determining specific gravities of whole blood and, after centrifuging, the plasma may be dropped into the solutions to determine the specific gravity of the plasma.

The normal range of plasma for men and women is 1.028 to 1.024. Great care must be used in preparing the solutions and in preparing the oxalated tubes for collecting the blood samples, in order to have accurate results.

The blood is dropped from a needle or pipet from a height of 1 cm. above the surface of the solutions. The solution the specific gravity of which is identical with that of the blood or plasma used will cause the drop to hesitate toward the center of the solution for about ten seconds, then slowly descend to the bottom.

Determinations were made for all patients soon after admission and at frequent intervals thereafter, particularly during the course of plasma and whole blood transfusions. For example, determinations were always made after two thirds of the estimated amount of blood required had been given; this enabled a reevaluation of the blood needs more accurately.

RESULTS

The copper sulfate method was found to have the great advantage of simplicity. It could be used at the bedside of the patient, in the operating room or in clinical laboratories. The actual determination was usually made clinically at the bedside, but if large numbers of patients were involved the specimens were collected in oxalated bottles for determination in the laboratory.

Correlations.—The results obtained by the copper sulfate method compare favorably with those obtained by photoelectric determination of hemoglobin, as is shown in table 1. There was also a good relation

1. Phillips, R. A.; Van Slyke, D. D.; Dole, V. P.; Emerson, K., Jr.; Hamilton, P. B., and Archibald, R. M.: The Copper Sulfate Method for Measuring Specific Gravities of Whole Blood and Plasma, Bull. U. S. Army M. Dept., December 1943, no. 71, p. 66; New York, Josiah Macy, Jr. Foundation, 1945; Chicago, E. H. Sargent and Co., 1946.

1a. E. H. Sargent and Company, 155 East Superior St., Chicago, are national distributors of the special copper sulfate crystals and standards needed for these estimations. The solutions used in the studies reported here were made up in accordance with the instructions of Phillips and others.[1]

between the specific gravity of the plasma and Kjeldahl analyses for total proteins, as shown in table 2. The method was found to be accurate to plus or minus 0.1 Gm. of protein per hundred cubic centimeters of plasma with not over 0.3 Gm. variation. It did not appear that shock or other allied conditions affected the accuracy. In normal

TABLE 1.—*Comparative Data on Hematocrit and Hemoglobin Values Obtained by Different Methods*

Specimen	Hemoglobin *	Hemoglobin †	Hematocrit Value (Determined)‡	Hematocrit Value (Calculated)	Red Blood Cell Count
1	11.4	11.0	37.0	34.0	3,080,000
2	12.0	13.5	38.0	40.0	4,010,000
3	12.8	13.4	42.0	38.9	3,620,000
4	12.8	13.2	40.0	42.2	5,250,000
5	12.5	13.0	37.0	39.0	4,230,000
6	11.1	11.4	35.0	34.0	3,980,000
7	11.0	11.3	35.0	33.0	4,480,000
8	15.4	14.0	43.0	39.0	3,980,000
9	12.7	12.8	39.0	37.0	4,260,000
10	15.2	13.8	51.0	49.0	4,000,000
11	11.4	11.9	33.5	35.0	3,810,000
12	14.1	13.2	37.0	39.5	3,620,000
13	14.5	13.8	45.0	40.0	3,960,000
14	12.2	12.8	44.0	38.0	4,010,000
15	12.5	14.2	44.0	42.5	4,000,000
16	13.8	15.3	42.0	45.5	4,280,000
17	13.7	12.7	43.0	37.5	3,890,000
18	12.3	12.7	51.0	51.5	4,700,000

* These values were obtained from the photoelectric determinations of hemoglobin.
† These values were obtained by the copper sulfate method.
‡ Hematocrit values were determined by centrifuging (obtained from Chief of Laboratory Service, Lieut. Col. Harry Agress).

TABLE 2.—*Determinations by Copper Sulfate Method*

	Healthy Normal Persons					
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Hematocrit value.....	48.8 (determined 50.2)	50.5	55.0	46.0	50.0	55.0
Hemoglobin.....	16.6 (photoelectric 16.8)	17.0	17.0	15.5	16.8	18.5
Total plasma protein.....	7.15	6.8	6.8	7.5	7.15	7.5

and pathologic bloods in which hemoglobin concentration within the red cells is not affected, the hemoglobin content by the specific gravity of whole blood was found regularly to be within 2 per cent of the correct value, as measured by the oxygen-carrying capacity, or plus or minus 0.3 Gm. of hemoglobin per hundred cubic centimeters.[1] The discrepancies were greater in determination of hematocrit values than for hemoglobin, but the correlation between the two is illustrated in table 1. This table also shows that red blood cell counts vary considerably

and proved to be a less accurate index of the concentration of red cells. This seemed to be particularly true in patients who were in shock, especially if the count was made from blood taken from puncture of a finger rather than a vein.

The Amount of Blood Given.—In calculating the amount of whole blood required by the patient who had suffered severe hemorrhage, the basis was an empiric observation that the transfusion of 500 cc. of whole blood increased the patient's hemoglobin concentration by 0.9 Gm. The use of the copper sulfate method, particularly when it

TABLE 3.—*Initial Determinations on Admission of One Hundred and Sixty-Six Orthopedic Battle Casualties*

Hemoglobin in Grams (Copper Sulfate Method)	20-29	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51
15.0	..	..	..	..	..	..	12	3	3
14.6 - 15	..	..	..	..	..	7	1	..	..
14.1 - 14.5	..	..	..	..	..	7	..	..	..
13.6 - 14	..	..	..	..	8	4	..	..	..
13.1 - 13.5	..	..	..	..	13	..	..	..	..
12.6 - 13	..	..	..	10	..	..	..	..	..
12.1 - 12.5	..	..	..	13	..	..	..	..	..
11.6 - 12	..	..	8	..	..	..	..	1	..
11.1 - 11.5	..	1	8	..	..	..	..	..	..
10.6 - 11	1	4	3	2	..	..	..	..	..
10.1 - 10.5	2	16	..	..	..	..	..	..	..
9.6 - 10	4	1	..	..	..	..	..	..	..
9.1 - 9.5	11	..	..	..	..	..	..	..	..
8.6 - 9	7	..	..	..	..	..	..	..	..
8.1 - 8.5	6	..	..	..	..	..	..	..	..
7.6 - 8	3	..	..	..	..	..	..	..	..
7.1 - 7.5	5	..	..	..	..	..	..	..	..
6.5 - 7	..	..	..	..	..	..	1	..	..

was repeated after two thirds of the calculated amount had been given, enabled an accurate estimation of the amount of blood actually required.

In 91 surgical cases, mostly major orthopedic injuries with infected wounds, an average of 2,360 cc. of whole blood was given during the four day preoperative and two week postoperative periods. This could be divided into an average of 1,060 cc. before and 1,300 cc. during and after operation. The copper sulfate method and the rule of giving 500 cc. of whole blood for every 0.9 Gm. of hemoglobin below the normal 15 Gm. per hundred cubic centimeters was used in treating these patients. Also 98 general surgical patients had copper sulfate determinations, and 93 of them received an average of 1,470 cc. of whole blood per patient. The amounts ranged from 500 to 6,500 cc. per patient. In 27 patients who had similar injuries without appreciable sepsis and

who did not require penicillin, an average of 1,800 cc. of whole blood was given in the same period, with but 200 cc. of blood plasma needed. There were 7 patients treated for various conditions with penicillin without operation who received only 800 cc. of whole blood and less than 1 unit of plasma per patient.

Fifty per cent (89) of 166 casualties had on admission to a general hospital hemoglobin values below 12 Gm. despite numerous transfusions (table 3).

One patient with a compound comminuted fracture of the upper third of the left femur and colostomy after an abdominal wound due to a shell fragment had a hematocrit value of 28.5, 9.6 Gm. of hemoglobin and 6.13 Gm. of total proteins the day of admission. Despite a liter of blood, the values were not much different the next day. A total of 8,150 cc. of whole blood was given over a month's time. Rib resection for drainage of empyema and drainage of urine through a wound in the thigh contributed to the need for whole blood. It was only because of the use of a simple accurate method of estimation of blood requirements that it was possible to keep the protein and hemoglobin near normal without undue fluctuation.

Space does not permit a detailed account of the results of each day's copper sulfate determination for these patients.

Two other patients were admitted with fractured femurs and multiple soft tissue wounds. One looked much paler than the other, who did not appear to be anemic. The hematocrit and hemoglobin values in the latter were reduced to about one-half normal, however, while the former had values only one-fourth below normal. This and numerous other instances convinced us that the use of such a method not only enabled us to treat our patients more intelligently, but was a real help in assuring adequate nutrition to promote early wound healing and recovery. Amino acid solutions parenterally were used in a few cases of chronic disease, in addition to whole blood and plasma.

Reactions.—In over two thousand transfusions in a two month period, there were only four reactions due to blood of the wrong type. The transfusions were stopped before more than 50 to 100 cc. had been given. The blood was returned to the laboratory and was found, after careful tests, to have been the wrong type. (The transfusions caused no fatality and no apparent renal damage.) This emphasized the value of carefully watching the patient during the transfusion, especially during the first few minutes. Two patients with severe wounds of the ilium and the abdomen died in uremia, present on admission. The effects of blood hematin on the kidneys was found in one, but there was no record of any mismatched blood being given. In the second, the

Rh factor was excluded. The effect of sulfonamide drugs on the renal function was thought to be important from gross examination of the kidneys in these 2 cases, although no crystalline deposits were seen by the pathologist. Further discussion of these problems may be found in the literature.[2] Whether myohematin from muscle necrosis in large areas in the absence of a tourniquet was a factor is debatable. There is a renal damage from it in crushing injuries.[3]

A single measurement of the blood pressure is not a good indication of the degree of shock in borderline cases.

COMMENT

The evidence herein presented clearly indicates that the copper sulfate method, when used on whole blood, seems to be just as accurate as hematocrit readings or measurements of hemoglobin concentrations or red blood cell counts. In this way the degree of hemoconcentration which produces an increase in specific gravity as well as hemodilution which produces a decrease in specific gravity can be readily measured. The method can be used readily at the bedside and seems to show, particularly when repeated determinations were made, that the blood requirements of a patient with a definite but stabilized blood volume can be sufficiently accurately determined to be of practical clinical significance. In using these measurements, it was assumed that 500 cc. of whole blood will raise the patient's hemoglobin concentration by 0.9 Gm. Actual measurements seem to justify the use of this basic measurement and indeed seem to be more valuable than the use of a modified burn formula, which was also used. Of obvious importance is the type of injury and in particular the question whether the hemoconcentration has occurred after loss of blood or the hemodilution after loss of plasma. In either case a deceptively normal value will be obtained. An important factor was the use of many determinations which changed with the varying clinical conditions and with therapy. A single copper sulfate determination was therefore of little value.

Adams and Ballou [4] found that in 55 of 128 cases, or 44 per cent, the differences between the total protein values by the copper sulfate

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2. (*a*) McKee, F. W.; Laycock, C. F.; Martens, T. G., and Nicholl, R. J.: Hemorrhagic Shock: The Relative Effect of Saline, Washed Red Cells, and Heparinized Plasma in Dogs, Surg., Gynec. & Obst. **78**:509 (May) 1944. (*b*) Allen, J. G.; Clark, D. E.; Thornton, T. F., Jr., and Adams, W. E.: The Transfusion of Massive Volumes of Citrated Whole Blood and Plasma in Man: Clinical Evidence of Its Safety, Surgery **15**:824 (May) 1944.

3. Bywaters, E. G. L.: Ischemic Muscle Necrosis, J. A. M. A. **124**:1103 (April 15) 1944.

4. Adams, M. A., and Ballou, A. N.: A Comparison Between the Values for Plasma or Serum Protein as Obtained by the Specific Gravity and the Micro-Kjeldahl Methods, J. Lab. & Clin. Med. **31**:507 (May) 1946.

and the micro-Kjeldahl methods did not exceed 0.3 Gm. per hundred units of serum. This percentage was slightly lower when the albumin was less than normal or the globulin above normal. They used serum instead of plasma for total protein determinations by the copper sulfate method; the routine measurement of the given amount of blood from a syringe by various persons is not accurate in the oxalate method.

Atchley and his co-workers [5] found a much greater degree of accuracy than Ballou by the copper sulfate method as compared to the micro-Kjeldahl method for total proteins.

These possible criticisms of the method are offset by its accuracy for hemoglobin-hematocrit determinations. In our hands there was sufficient accuracy for total protein determinations to be of definite clinical value.

TABLE 4.—*Initial Copper Sulfate Determination for Battle Casualties on Surgical Wards,* Total Proteins, Grams Per Hundred Cubic Centimeters*

	Total Proteins, Gm. per 100 Cc.								
Hematocrit Value	4.0-5.0	5.0-5.5	5.6-6.0	6.1-6.5	6.6-6.7	7.1-7.5	7.6-8.0	8.1-8.6	Total
16 - 20	0	0	1	0	0	0	0	0	1
21 - 29	3	2	8	6	3	0	0	0	22
30 - 32	0	0	8	7	1	1	0	0	17
33 - 36	0	2	2	13	2	2	1	1	23
37 - 39	0	0	2	5	1	1	0	0	9
40 - 42	0	0	0	7	2	1	0	0	10
43 - 45	0	1	1	3	4	2	0	0	11
46 - 48	0	1	0	0	1	1	0	0	3
49 - 51	0	0	0	0	1	0	0	0	1
51 - 60	0	0	0	0	0	1	0	0	1
Total	3	6	22	41	15	9	1	1	98

* This table was prepared by Pvt. J. F. Burns, from data from laboratory files of Lieut. Col. Harry Agress.

Normal values were not infrequently found initially in patients with severe wounds and a history of hemorrhage. This paradox is obviously due to hemoconcentration. Should this normal determination be taken at its face value, serious difficulty will ensue because the additional loss of a few hundred cubic centimeters of blood, especially with the added trauma of operation, may be enough to cause the patient to go into shock [6] (table 4). Clearly, therefore, the history of a case is just as important as the laboratory values. Otherwise, the discrepancy can

5. Atchley, J.; Bacon, R.; Curran, G., and David, K.: A Clinical Evaluation of the Copper Sulfate Method of Measuring Specific Gravities of Whole Blood and Plasma, J. Lab. & Clin. Med. **30**:830 (Oct.) 1945.

6. Lyons, C.: Penicillin Therapy of Surgical Infections in the U. S. Army, J. A. M. A. **123**:1007 (Dec. 18) 1943. Evans, E. I.; James, G. W., III, and Hoover, M. J.: Studies on Traumatic Shock: II. The Restoration of Blood Volume in Traumatic Shock, Surgery **15**:420 (March) 1944.

only be detected by blood volume determinations. Measurements have been made [7] on patients soon after injury and have shown that the blood volume is 30 to 40 per cent below normal with clinical manifestations

TABLE 5.—*Initial Copper Sulfate Determination for Battle Casualties in All Surgical Wards*

Hematocrit Value	Total Protein, Gm. per 100 Cc.						
	5.6-6.0	6.1-6.5	6.6-7.0	7.1-7.5	7.6-8.0	Total	Percentage
29 - 29	86	55	12	8	2	163	21.2
30 - 32	33	32	7	1	0	73	9.5
33 - 35	31	39	26	9	2	107	14.0
36 - 38	24	61	23	24	3	135	17.5
39 - 41	16	40	42	15	7	120	15.6
42 - 44	5	29	35	26	3	98	12.7
45 - 47	4	11	21	15	3	54	7.0
48 - 50	0	4	3	3	1	11	1.4
50 - 60	0	0	3	2	2	7	0.9
Total	199	271	172	103	23	768	
Percentage	26	35	22.4	13.4	3		

TABLE 6.—*Determinations of Total Proteins* (Heparinized Samples)*

Specific Gravity, Copper Sulfate Method	Biuret Method Checked with Micro-Kjeldahl Method	Difference Between the Methods
7.4	7.0	0.4
6.3	6.3	0.0
5.9	6.0	0.1
6.8	6.7	0.1
6.3	6.6	0.3
6.4	6.3	0.1
8.2	8.2	0.0
5.7	5.8	0.1
5.5	5.7	0.2
7.4	7.7	0.3
7.5	7.6	0.1

Heparinized blood gave consistently higher values than oxalated blood for total proteins and hematocrit values for the same sample of blood in the same laboratory. Oxalate bottles with average amounts of oxalate such as are prepared routinely in most hospitals may cause a decrease in plasma specific gravity unless the kind and amount of oxalate and amount of blood added are carefully controlled.

* Obtained with the help of Dr. Robert King.

of shock following skeletal trauma and/or hemorrhage. It was also found that on the average 1.5 to 2 liters of blood was required for replacement. The conditions responsible for hemoconcentration and

7. Noble, R. P., and Gregerson, M.: I. Blood Volume in Clinical Shock; II. The Extent and Cause of Blood Volume Reduction in Traumatic, Hemorrhagic, and Burn Shock, J. Clin. Investigation **25:** 172 (March) 1946.

hemodilution must be carefully differentiated on a clinical basis.[8] In most skeletal trauma with simple hemorrhage, the loss of blood is associated with hemodilution (table 5). On the other hand, in burns and abdominal injuries with peritonitis, selected loss of plasma occurs at the site of injury or infection and the ensuing reduction in blood volume is attended by hemoconcentration.[7] In addition, however, there is probably some other factor than local loss of fluid, particularly in the case of so-called tourniquet or crush syndrome.[9]

In the care of these patients, the value of a roving consultant trained in the intricacies of preoperative and postoperative care proved of great value for patients during critical phases of treatment. Entirely apart from the use of blood and plasma the nutritional intake was found to be extremely important, and measures were taken to insure an intake of at least 70 Gm. of protein daily, and from 120 to 140 Gm. of proteins daily in many patients, in order to prevent depletion of protein reserves during convalescence.[10]

During these observations no evidence of toxic effects from the use of citrated blood was observed. In dogs, the toxic dose was found to be 0.3 Gm. per kilogram of body weight [2b] when given in fifteen minutes or less. Most of our patients got 0.1 to 0.3 Gm. per kilogram in two or more hours, inasmuch as each 500 cc. flask of blood contains 70 cc. of 2.5 per cent sodium citrate solution.

SUMMARY

This report is based on a study of 166 patients admitted to a general hospital overseas for whom a simple, accurate copper sulfate specific gravity method was used to determine hemoglobin and hematocrit values as well as concentration of total proteins. The values obtained were found to check closely with determinations obtained by more orthodox methods. Blood needs could be readily calculated on a basis that 500 cc. of whole blood increased the hemoglobin 0.9 Gm. Fluid balance must be restored and dehydration corrected before this rule of thumb can be applied literally.

An average of 2,360 cc. of whole blood was required during a four day preoperative and a two week postoperative period. In 98 cases of

8. Elman, R.; Lischer, C. E., and Davey, H. W.: Plasma Proteins (Albumin and Globulin) and Red Cell Volume Following a Single Severe Non-Fatal Hemorrhage, Am. J. Physiol. **138:** 569 (March) 1943.

9. Scott, C. C.: Failure of Local Fluid Loss to Account for Death in Experimental Shock, J. Clin. Investigation **25:**153 (March) 1946.

10. Nutritional Aspects of Convalescent Cases: Report of Committee on Convalescence and Rehabilitation of the National Research Council, Bull. U. S. Army. M. Dept., May 1944, no. 76, p. 85.

less severe disease an average of 1,470 cc. of whole blood was required per patient during a similar period.

When admitted to the hospital, half of all patients had hemoglobin values below 12 Gm. and total proteins below 6.6 Gm., and 69 per cent of the patients had hematocrit readings below 40. Changes in these values, particularly before and after therapy, proved of even greater value than the initial measurement.

The copper sulfate specific gravity method of determining hemoglobin, hematocrit and total proteins with the use of a line chart proved to be simple, yet accurate enough for clinical use.

Robert Elman, M.D., gave helpful criticism during the final writing of this paper.

NOTE.—In normal and miscellaneous medical patients, Dr. R. A. Phillips and others, comparing the gravities with plasma proteins estimated by exact macro-Kjeldahl analyses, have shown statistically that the most precise results for such plasmas are calculated by the equation: $P = 389.6\ (G_p - 1.0079)$. This gives plasma protein concentrations about 0.2 Gm. per hundred cubic centimeters higher than the equation used previously and the line charts 1 and 2.

TOTAL GASTRECTOMY

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BY DEFINITION total gastrectomy is the removal of the entire stomach along with a cuff of esophagus, above, and of duodenum, below. Such an operation has now become accepted as a recognized surgical procedure for the treatment of certain lesions of the stomach which cannot be dealt with adequately by partial or subtotal gastrectomy. The lesions which most often require complete gastrectomy are those carcinomas or lymphosarcomas which involve the greater part of the stomach. From the technical standpoint the small "leather bottle" stomach, or linitis plastica, due to a diffuse infiltrating scirrhous carcinoma, has generally been regarded as the type best suited to this operation. In addition, smaller malignant neoplasms situated in the upper half or upper third of the stomach are best treated by total gastrectomy. Large neurofibromas or leiomyomas with or without sarcomatous degeneration which extend into the upper portion of the stomach are particularly favorable for cure, since, in spite of their large size, these tumors are either benign or of a low grade of malignancy. Juxtaesophageal gastric ulcer, if dealt with by gastric resection by the abdominal route, is best managed by complete gastrectomy, since conservation of the lower portion of the stomach is unnecessary, and probably undesirable, and adds considerably to the difficulties of a satisfactory reconstruction.

As experience with total gastrectomy in many surgical clinics has increased the technical details of the procedure have become fairly well standardized. This, with the many advances in preoperative and postoperative care which have been made during recent years and the many suitable methods of anesthesia now available, has resulted in a reduction of the operative mortality to a level which, while still disturbingly high, is nevertheless not prohibitive. Moreover, sufficient follow-up studies have been made on patients who have survived the operation to indicate that a person may live a reasonably normal and comfortable life in the complete absence of the stomach.

From the Department of Surgery, University of Michigan.

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In an exhaustive review of the literature in 1929, Finney and Rienhoff [1] collected 62 cases of total gastrectomy and added 5 of their own. There were 36 operative deaths in these 67 cases, or an operative mortality of 53.8 per cent. The longest period of survival after operation in this series was four years and eight months. In 1938 Allen [2] reported 16 cases of total gastrectomy from the Massachusetts General Hospital and emphasized certain technical details which he considered important for the success of the operation. These were; (1) restoration of gastrointestinal continuity by esophagojejunostomy rather than an attempt at esophagoduodenostomy; (2) attachment to the diaphragm of the loop of the upper portion of the jejunum used in the anastamosis in order to prevent strain on the suture line; (3) enteroenterostomy between the afferent and the efferent limb of the jejunal loop; (4) catheter jejunostomy for feeding during the early postoperative period, and (5) maintenance of suction from within the esophagus during the time that this structure is open by means of a Levine tube connected with the Wangensteen suction apparatus. His operative mortality was 50 per cent. The longest period of survival following operation was four and one-half years. In a recent communication Allen [3] (1946) presented data on the entire series of total gastrectomies for cancer performed at the same hospital. There were 84 cases, in 30 of which operation was performed by the transthoracic route. The over-all mortality rate for the entire series was 40 per cent. One patient had survived ten and a half years, and another five and a half years, without signs of recurrence. Lahey and associates,[4] in several articles on this subject, emphasized certain technical details, notable among which was the development of anterior and posterior peritoneal flaps from the diaphragm to be sutured over the anastomosis on its completion, thereby minimizing the danger of leakage and reducing tension. Lahey stated that he invariably employs an antecolic esophagojejunal anastomosis. In his most recent paper (1946) [5] he reported 89 cases, with 26 deaths, an operative mortality of 29.2 per cent,

1. Finney, J. M. T., and Rienhoff, W. F., Jr.: Gastrectomy, Tr. South. S. A. **40**:424, 1927.

2. Allen, A. W.: (*a*) Carcinoma of the Stomach, with Special Reference to Total Gastrectomy, Ann. Surg. **107**:770, 1938; (*b*) Total Gastrectomy for Carcinoma of the Stomach, Am. J. Surg. **40**:35, 1938.

3. Allen, A. W.: Personal communication to the author, November 1946.

4. Lahey, F. H.: Complete Removal of the Stomach for Malignancy: Report of Five Surgically Successful Cases, Surg., Gynec. & Obst. **67**:212, 1938. Lahey, F. H., and Marshall, S. F.: Combining Splenectomy with Total Gastrectomy, ibid. **73**:341, 1941; Indications for, and Experiences with, Total Gastrectomy, Based upon Seventy-Three Cases of Total Gastrectomy, Ann. Surg. **119**:300, 1944.

5. Lahey, F. H.: Gastric Surgery, New England J. Med. **234**:809, 1946.

although during the last three and one-half years the mortality had fallen to 16.3 per cent. His oldest living patient was alive and well eight years and seven months after operation, the procedure having been performed for a large leiomyosarcoma involving all the stomach. His follow-up studies indicate that of the patients who survive the operation 59.7 per cent will live twelve months, 38.6 per cent eighteen months, 29.8 per cent twenty-four months and 21.1 per cent thirty-six months or more.

Jones and Kehm [6] (1945) reported 8 consecutive cases of total gastrectomy, with no deaths. These patients were all living from six to eighteen months after the operation. In 1943 Pack and McNeer [7] reviewed all the cases reported in the literature up to July 1, 1942 and added 20 of their own. In these 20 cases there were 6 deaths, or an operative mortality of 30 per cent. In considering the total number of 303 cases assembled, it was observed that prior to 1921 the mortality was 49.3 per cent, whereas from 1921 to 1930 it was 31.6 per cent and from 1931 to 1942 it was 34.3 per cent. In their own group of patients, 1 was alive and well two years and eight months after operation. Horsley [8] (1943) reported successful results in 3 consecutive cases of complete gastrectomy. Prior to this he had performed the operation in 12 cases with a fatal outcome in all. Graham,[9] having had unsatisfactory results with the usual methods of esophagojejunostomy in his earlier experience, described an ingenious method of enclosing the anastomosis between the afferent and the efferent jejunal limb which had given good results in his hands. This technic has since been adopted by many surgeons.

MATERIAL

During the nine year period from October 1937 to October 1946, complete gastric resection was performed by the abdominal route in 60 cases.[10] The gastric lesions for which the procedure was carried out are listed in table 1. Of the 60 patients, 41 were men and 19 women. The oldest patient in the series was 81 and the youngest 30 years of age, the average age being 55 years.

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6. Jones, T. E., and Kehm, R. W.: Total Gastrectomy: Report of Eight Cases, Surg., Gynec. & Obst. **80**:534, 1945.

7. Pack, G. T., and McNeer, G.: Total Gastrectomy for Cancer: A Collective Review of the Literature and an Original Report of Twenty Cases, Internat. Abstr. Surg. **77**: 265, 1943; in Surg., Gynec. & Obst., October 1943.

8. Horsley, J. S.: Three Successful Cases of Total Gastrectomy, Virginia M. Monthly **70**:549, 1943.

9. Graham, R. R.: Technique for Total Gastrectomy, Surgery **8**:257, 1940.

10. Since the completion of this paper, total gastrectomies have been successfully performed for cancer in 2 additional cases.

Carcinoma.—As in all the previously reported series, carcinoma provided the most common indication for the operation, and it was for this lesion that the procedure was performed in 53 of the cases. In the experience of my associates and myself, three types of lesions have been encountered which have required removal of the entire stomach (fig. 1).

(*a*) Lesions which involve all, or nearly all, of the stomach. This group includes both the small "leather bottle" stomach, due to infiltrating scirrhous carcinoma, and the large adenocarcinomas, which in some instances may have invaded the greater part of the gastric wall and still have not extended grossly beyond the stomach except for involvement of the regional lymph nodes along the two curvatures (fig. 2).

(*b*) Smaller lesions situated high on either curvature or on the anterior or posterior wall in such a manner as to make adequate resection impossible except by removal of the lower end of the esophagus (fig. 3).

TABLE 1.—*Lesions of the Stomach for Which Total Gastrectomy Was Performed on Sixty Patients*

Lesion	No. of Patients	No. of Operative Deaths	Mortality, per Cent
Carcinoma	53	12	22.6
Gastric ulcer	4	1	25
Lymphosarcoma	2	1	50
Neurofibroma	1	0	0
Total	60	14	23.3

(*c*) Sessile or polypoid lesions occurring in the lower or middle portion of the stomach but with indefinite intramural extension cephalad, as evidenced by thickening and friability of the gastric wall proximal to the lesion. On some occasions this proximal involvement was detected only when the stomach was transected for a proposed subtotal resection. In doubtful cases specimens taken at this level for microscopic examination of frozen sections will usually clarify the situation.

The operative mortality in this group of 53 cases was 22.6 per cent.

Lymphosarcoma.—The problems presented by lymphosarcoma of the stomach are essentially the same as those of carcinoma. This lesion, while of relatively rare occurrence, requires the same radical treatment. There were 2 cases of this tumor in the present series. In 1 case the growth involved the entire stomach and had extended into the pancreas, and the regional lymph nodes were extensively involved. In view of this fact, a course of irradiation was given after operation, but the patient died exactly six months later as a result of generalized lymphoblastomatosis. In the second case the lesion was confined to the

upper half of the stomach and there was involvement of some of the regional lymph nodes. This patient died on the third postoperative day. Autopsy revealed that death was caused by general peritonitis, due to partial separation of the esophagojejunal anastomosis. Lymph

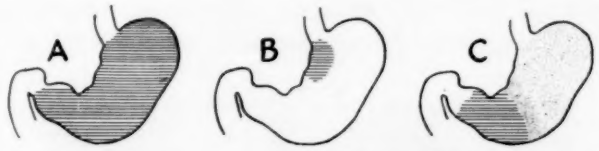

Fig. 1.—Diagram showing extent of involvement of the stomach by malignant lesions treated by total gastrectomy, 55 cases. *A*, lesions involving all, or nearly all, of the stomach, 36 cases; *B*, smaller lesions situated in the upper half of the stomach, 11 cases; *C*, lesions in the lower portion of the stomach with indefinite extension upward, due to intramural spread, 8 cases.

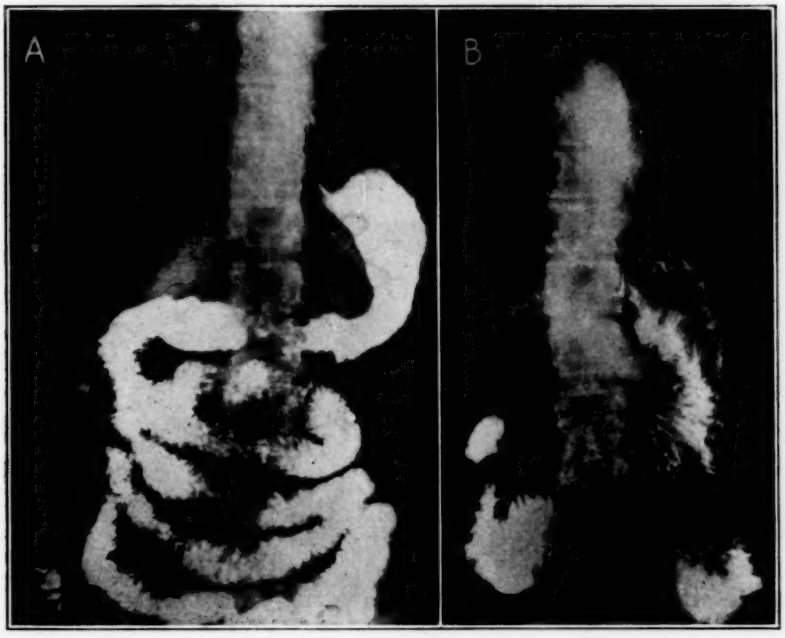

Fig. 2.—*A*, typical roentgenologic appearance of diffusely infiltrating scirrhous carcinoma of the stomach (linitis plastica), showing a small, tubular stomach. Fluoroscopic study showed that the stomach emptied rapidly. In serial roentgenograms there was no evidence of peristaltic waves.

B, roentgenogram made four months after operation, showing partial obstruction at the site of the esophagojejunal anastomosis. A second operation revealed this to be due to extensive recurrence of the neoplasm.

nodes in the mesentery were observed to contain foci of lymphosarcoma, indicating the desirability of postoperative irradiation in all cases of this neoplasm.

Benign Tumors.—There was only 1 case of total gastrectomy for benign gastric tumor in this series. This case was that of a woman aged 40 who in June 1938 had a total gastrectomy for a large hourglass neurofibroma involving the entire lesser curvature of the stomach. She is living and in a good state of nutrition at the present time, eight years and four months after the operation. Metabolic studies made four years after operation have been reported in detail.[11] Since that publication the patient has been carefully followed, and no important changes have been noted.

Fig. 3.—Preoperative roentgenogram showing extensive involvement of the upper half of the stomach by carcinoma. The lesion was situated chiefly along the greater curvature and the posterior wall. This patient is in excellent health, eight years after total gastrectomy.

Gastric Ulcer.—In 4 cases a chronic benign gastric ulcer was treated by total gastrectomy. In all cases there was an ulcer high on the lesser curvature or the posterior wall, and the lesion had originally been

11. Farris, J. M.; Ransom, H. K., and Coller, F. A.: Total Gastrectomy: Effects upon Nutrition and Hematopoiesis, Surgery **13**:823, 1943.

diagnosed as benign on the basis of roentgenographic and gastroscopic studies (fig. 4). Intensive medical treatment over a prolonged period failed to result in healing, and its malignancy was accordingly suspected. At the time of operation, the lesions were observed to be penetrating ulcers, and their malignant character could not be excluded. Since gastric resection seemed mandatory in view of the high position of the lesion total gastrectomy was elected. There was 1 fatality in this group. The final microscopic studies showed that all the lesions were benign. In view of this mortality of 25 per cent, it would seem that complete gastrectomy is probably not the best procedure for such a juxtaesophageal ulcer. On the other hand, palliative gastrectomy, as recommended by Colp,[12] leaves a possibly malignant lesion in situ, as would also simple gastroenterostomy or transthoracic vagotomy. Possibly, local excision of the ulcer combined with gastroenterostomy or trans-

Fig. 4.—Benign juxtaesophageal gastric ulcers treated by total gastrectomy, 4 cases.

thoracic resection of the upper portion of the stomach with its contained ulcer, according to the suggestion of Sweet,[13] would be superior and safer.

TECHNICAL CONSIDERATIONS

Preliminary Preparation.—Since most patients with gastric lesions evince signs of serious nutritional disorders, with dehydration, anemia and avitaminosis, a fairly long period of preparation is necessary for their rehabilitation. Blood transfusions are used freely, and ascorbic acid and vitamin B complex are administered in large quantities. Vitamin K is added if there is a prothrombin deficiency. Particular attention to oral hygiene is important, since contamination of the operative field by oral secretions inevitably occurs to some degree, inasmuch as an aseptic type of anastomosis between the esophagus and the jejunum is not feasible. A preliminary course of sulfadiazine or penicillin for a few days prior to operation probably affords additional protection. Care should be exercised in minimizing the amount of preoperative sedation. The patient comes to the operating room with an indwelling Levine tube in the stomach, and this is attached to the

12. Colp, R., and Druckerman, L. J.: Palliative Gastrectomy in Selected Cases of Gastric Ulcer, Ann. Surg. **124**:675, 1946.

13. Sweet, R. H., in discussion on Colp and Druckerman.[12]

Wangensteen suction apparatus so that suction can be maintained during the operative procedure. A needle is placed in an arm vein before the operation is started so that the proper fluids may be given continuously.

Anesthesia.—Good relaxation is essential in providing satisfactory exposure and in minimizing the difficulties of the esophagojejunal anastomosis. Spinal anesthesia was used in a number of cases, with satisfactory results. However, unless some type of continuous spinal anesthesia is used, in view of the long duration of the operation, it will ordinarily be necessary to resort to inhalation anesthesia for the latter part of the procedure. Endotracheal anesthesia induced with a nitrous oxide-oxygen-ether mixture has been found entirely adequate, and more recently endotracheal cyclopropane anesthesia aided by curare has proved satisfactory.

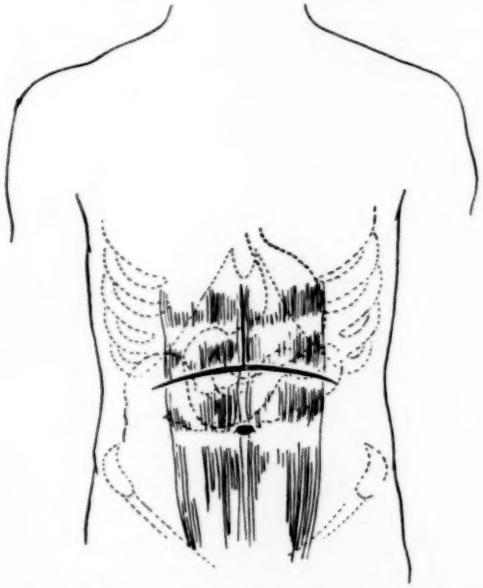

Fig. 5.—Incision recommended for total gastrectomy.

Incision.—An upper abdominal, slightly curved, transverse incision which transects both rectus muscles is now employed for practically all gastric operations in this clinic. Such an incision affords adequate exposure for total gastrectomy in many cases. If additional room is required, a vertical extension is added, the incision passing upward through the linea alba to the ensiform process (fig. 5). Closure, except for the peritoneum, is made with nonabsorbable suture material, stainless steel wire or silk being preferred. Wound infections have occurred somewhat more frequently with this than with the usual type of abdominal operation. In 1 instance a severe wound infection occurred and resulted in a large incisional hernia, which required surgical repair several months later. It is now deemed advisable to employ the method of delayed primary closure of the wound (Coller and Valk [14]) in most cases.

14. Coller, F. A., and Valk, W. L.: The Delayed Closure of Contaminated Wounds, Ann. Surg. **112**:256, 1940.

Operative Procedure.—In 57 cases the operative technic described by Allen was followed [2b] (fig. 6). In this operation a retrocolic anastomosis is preferred whenever possible, and it was employed in 52 cases in this series. Antecolic anastomosis was used in only 5 cases, in each of which certain anatomic peculiarities made the posterior connection impracticable. Whether an enteroenterostomy between the afferent and the efferent jejunal limb is essential is problematic. The anastomosis was performed in 30 cases and omitted in 27 cases. Little difference was noted in the convalescence and subsequent postoperative course in these two groups of patients. In a few cases in which no enteroenterostomy was performed and in which regurgitation or difficulty in eating persisted or occurred later, an adequate explanation was invariably found in other lesions, such as recurrent neoplasm or subphrenic abscess. The theoretic advantages of an enteroenterostomy, which have been mentioned, are the reduction in tension in the proximal jejunal loop during convalescence, which may safeguard the main anastomosis and the closed

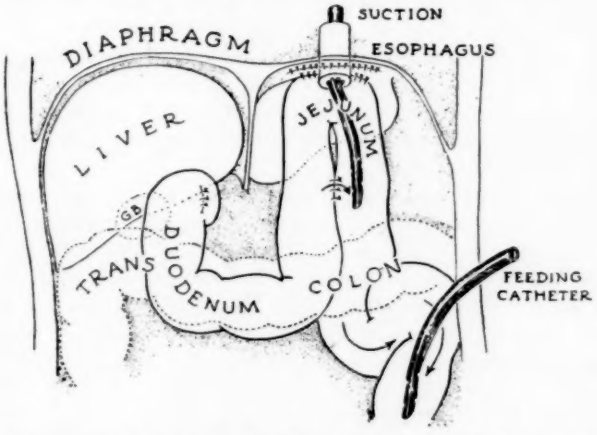

Fig. 6.—Diagrammatic sketch showing operation completed (redrawn from Allen [2b]).

duodenal stump, and the prevention of duodenal contents from entering the esophagus, a possible source of annoying pyrosis.

The method of reconstruction following removal of the stomach advocated by Graham was employed in only 3 cases. Graham recommended use of an antecolic anastomosis, and the enteroenterostomy in this operation is mandatory. In 2 cases the postoperative course was entirely smooth and uneventful, whereas in the third case, that of resection for ulcer, the patient died on the seventh postoperative day. Autopsy disclosed that death was due to volvulus of the proximal jejunal limb, with gangrene and multiple points of perforation and resultant general peritonitis. Horsley reported a similar accident and now advises anchoring the proximal limb of the jejunum to the duodenum.

A catheter jejunostomy for early postoperative feeding was employed in 49 cases and omitted in 11 cases. This simple expedient, in our opinion, is distinctly worth while. It requires only a few additional minutes at the time of operation for its establishment, and it simplifies the postoperative care in all cases. If complications at the esophageal anastomosis, such as obstruction or leakage, occur, it is of inestimable value. In a few instances in which a jejunostomy was not performed at the time of operation it became necessary to establish one as a

secondary operation. No difficulty has been encountered with persistent fistula or intestinal obstruction at the jejunostomy site.

Splenectomy often facilitates the operative procedure by improving the exposure. For this reason it is often performed, and it is also indicated when there is involvement by neoplasm of the spleen or the lymph nodes at the hilus. An additional indication for splenectomy is the troublesome bleeding occasionally encountered owing to laceration of the capsule or tearing of the organ. Theoretically, splenectomy is to be avoided, since the danger of postoperative thrombosis is increased. In this series it was performed in 24 cases, whereas it was unnecessary in the remaining 36 cases. In the cases in which the spleen was removed no complications were noted which could be attributed to this procedure.

As the esophagojejunal anastomosis is completed, the Levine tube is pushed down into the distal jejunal loop, and the Wangensteen suction is continued after the operation. It is believed that the aspiration of fluid minimizes tension on the suture line, and the splinting effect of the tube is probably desirable. The tube is now removed on the third or fourth day, as its prolonged use may lead to ulceration or necrosis at the suture line, as well as involving danger of necrosis of the cricoid cartilage. No attempt is made to give liquids or feeding through the tube, although the occasional instillation of a small amount of fluid may be desirable in order to make certain that the tube has not become plugged or the openings caught in mucosal folds.

My colleagues and I have discontinued almost entirely the local use of the sulfonamide drugs in the peritoneal cavity. Preferable to this, we believe, is a massive dose (80,000 to 100,000 units) of penicillin administered intravenously at the conclusion of the operation. Penicillin is continued in a dose of 40,000 units every three hours for several days after operation, or longer if indicated. A transfusion of at least 1,000 cc. of blood is given during the course of the operation, and additional blood is given during the postoperative period if necessary.

PATHOLOGIC STUDY

In the group of cases here reported total gastrectomy was ordinarily elected only when at the time of operation there seemed to be a reasonable chance for cure. In most cases, therefore, the problem was chiefly that of the local lesion and the involved regional lymph nodes. In none of the cases were there recognizable hepatic metastases, and in only a few cases were there small secondary deposits of tumor at other points in the abdominal cavity. Thus, the operation was not frequently employed as a definitely palliative procedure, since the present mortality rate would scarcely justify it. Subsequent events, however, have demonstrated that the operation was actually a palliative one in the majority of cases, as evidenced by the fact that 31 of the 42 patients with malignant disease who survived the operation have subsequently died. In all instances death was due to recurrence, as far as can be ascertained. Microscopic study of the specimens removed at operation disclosed several points of interest. Involvement of the regional lymph nodes was noted in both the cases of lymphosarcoma and in 36 of 46 cases of carcinoma in which a sufficiently careful study was made. In addition to examination of the usual sections taken from the main

neoplasm, special studies were made of tissue taken from both the upper and the lower end of the operative specimen in 44 cases of carcinoma. It was disappointing to note that submucosal infiltration by neoplasm was present in the esophageal end up to the line of transection in 21 cases whereas similar involvement of the duodenal end was noted in 13 instances (table 2). These data would indicate that

TABLE 2.—*Microscopic Observations in Cases of Carcinoma of Stomach Removed by Total Gastrectomy*

Ends of specimen (44 cases)	No. of Cases
Part of stomach *	
Upper +; lower −	14
Upper −; lower +	6
Both ends −	17
Both ends +	7
Involvement of regional lymph nodes (46 cases)	
Malignant tissue present	36
Nonmalignant tissue	10

* The plus sign indicates neoplastic infiltration; the minus sign, absence of neoplastic infiltration.

TABLE 3.—*Causes of Death * After Total Gastrectomy for Malignant Growths*

Cause of Death	No. of Cases
With Autopsy (12 Cases)	
Peritonitis (leak at esophagojejunal anastomosis)	7
Peritonitis (no leaks)	2
Pulmonary embolism and pneumonia	1
Subphrenic abscess	1
Volvulus of proximal jejunal loop (Graham operation)	1
Without Autopsy (2 Cases)	
Peritonitis (leakage at an esophagojejunal anastomosis)	1
Pneumonia	1

* The operative deaths numbered 14, with a mortality rate of 23.3 per cent.

a high rate of recurrence was to be expected, and such proved to be the case. In view of these observations, it is possible that total gastrectomy by the transthoracic route may in the future prove to be a superior type of procedure, since a longer segment of esophagus can be included in the resection.

OPERATIVE DEATHS

There were 14 operative deaths, or a mortality of 23.3 per cent. Postmortem examinations were made in 12 of these cases (table 3). The most frequent causes of death was general peritonitis, as it was demonstrated in 10 instances, and there was convincing clinical evidence that it was responsible for the fatal outcome in 1 of the cases in which autopsy was not performed. The most frequent source of the peritonitis

was leakage at the esophagojejunal anastomosis, since it was found in 7 of the cases in which autopsy was done. In 2 cases of general peritonitis all the suture lines were observed to be intact. In 1 case, as previously mentioned, the peritonitis occurred secondary to volvulus and gangrene of the proximal jejunal loop in a Roscoe Graham type of reconstruction. In 1 case death occurred on the twenty-third day after operation and was due to bilateral subphrenic abscess. This complication undoubtedly was due to a slow leak at the anastomosis. It was gratifying to note that pulmonary complications accounted for the death of only 2 patients.

Autopsy studies in the 11 cases of death following operation for malignant growths provide certain interesting data. In the 1 fatal case of lymphosarcoma residual foci of lymphosarcoma were present in the mesenteric lymph nodes, and this suggests the advisability of postoperative irradiation in all cases of this neoplasm. In only 2 of the remaining 10 cases in which the gastrectomy was performed for cancer was there demonstrable evidence of residual neoplasm at autopsy. In 1 case residual metastatic carcinoma was observed in the abdominal periaortic, peripancreatic and mesenteric lymph nodes, as well as in one ovary. In the second case metastatic carcinoma was present in the peripancreatic adipose tissue.

POSTOPERATIVE COURSE

Early Part of Course.—Barring cases in which fatal complications developed, the postoperative course in most cases in this series was extraordinarily smooth and uneventful. As previously mentioned, wound sepsis occurred more frequently than in the usual cases of subtotal gastrectomy. Fortunately, it was serious in only 1 instance. In 1 case a left subphrenic abscess developed, necessitating surgical drainage. Serious pulmonary complications were infrequent. This I attribute to early recognition of postoperative atelectasis and vigorous treatment by suction bronchoscopy or intratracheal catheter suction, as recommended by Haight and me.[15] Frequently, at the conclusion of the operative procedure, bronchoscopic aspiration was carried out in the operating room when there was evidence of retained secretions.

The Levine tube is usually removed on the third or fourth day and the patient allowed to begin taking small amounts of fluid with a fairly rapid progression to the usual diet for patients after operations on the stomach. The jejunostomy tube is removed in about a week. Patients are allowed to be up and about as early as possible; and since experi-

15. Haight, C., and Ransom, H. K.: Observations on Prevention and Treatment of Postoperative Atelectasis and Bronchopneumonia, Ann. Surg. **114:** 243, 1941.

ence has shown that an adequate daily caloric intake may be difficult to attain early in convalescence they are instructed at the time of discharge to take frequent, relatively small feedings With the passage of time most patients will be able to resume a fairly normal routine so far as eating habits are concerned and will maintain a satisfactory state of nutrition. Ferrous sulfate is prescribed, and its use should be continued indefinitely in order to prevent the development of hypochromic microcytic anemia, a condition which frequently follows gastrectomy, owing to interference with the metabolism of iron.

Late Part of Course.—After leaving the hospital, a few patients have experienced some difficulty in swallowing. The majority have no trouble of this sort. If the dysphagia is due to slight contraction at the stoma, a few gentle dilations with Hurst dilators will promptly remedy the situation. When symptoms have persisted, the cause has always been due to recurrence involving the stoma. One patient has experienced difficulty with regurgitation after eating for over a year following operation. Roentgenologic studies show a satisfactory stoma, but pronounced hypomotility of the small intestine is present. The case is unique in our experience. In only 2 cases has macrocytic anemia developed. In these cases symptoms did not become manifest until four and one-half and five and one-half years after operation. Studies of the blood revealed the typical changes of pernicious (addisonian) anemia, and prompt remission followed appropriate therapy.

Spontaneous hypoglycemia has been shown by Conn and Ricketts [16] and others to occur fairly often after total and subtotal gastrectomy. It only rarely is responsible for troublesome symptoms and is controlled with a high protein, low carbohydrate diet. A patient who has otherwise done well for over five years after a total gastrectomy for gastric ulcer continues to have distressing symptoms. In addition to the abnormal blood sugar curve, he presents serious psychiatric problems, and it is felt that his poor health is chiefly due to these factors.

END RESULTS

Forty-six of the 60 patients who were treated survived the operation, and of this number 31 have subsequently died. The latter group of patients, now dead, includes 1 patient with lymphosarcoma who survived for six months and 30 with carcinoma. The 3 patients who were successfully operated on for gastric ulcer and the 1 operated on for benign tumor are all living. Table 4 summarizes the duration of life following discharge from the hospital of the patients who died. Death was due to recurrence of the disease in all instances. Approximately

16. Conn, J. H., and Ricketts, W.: Unpublished data.

one-third lived for six months or less; one-third, from six months to one year, and one-third, for more than one year. The average duration of life in this group was ten and one-half months.

In table 5 data are given concerning the 11 patients who were operated on for carcinoma and who are still living. It will be noted that one half of them were operated on too recently for evaluation of the results. Two of these patients already exhibit signs of recurrence.

TABLE 4.—*Postoperative Course of Thirty-One Patients Who Survived Total Gastrectomy and Subsequently Died* *

Survival Period	No. of Patients
6 mo. or less	10
6 to 12 mo.	9
12 to 18 mo.	10
18 to 24 mo.	1
Over 2 yr.	1

* Thirty patients had carcinoma and 1 patient lymphosarcoma. The longest survival period was two years four and one-half months; the shortest survival period, two months; the average survival period, ten and one-half months.

TABLE 5.—*Data on Eleven Patients Still Living After Total Gastrectomy for Carcinoma*

Patient No.	Sex	Present Age, Yr.	Period	Result
1	M	57	7 yr. 11 mo.	Excellent
2	F	71	6 yr. 1 mo.	Good (macrocytic anemia)
3	M	64	4 yr. 5 mo.	Good
4	F	39	1 yr. 6 mo.	Good (regurgitation)
5	M	70	1 yr. 5 mo.	Good
6	M	57	8 mo.	Good
7	M	64	8 mo.	Poor (recurrence)
8	F	40	6 mo.	Good (recurrence)
9	M	58	3 mo.	Good
10	F	81	3 mo.	Good
11	M	62	1 mo.	Good

Two patients have survived for eighteen months and are doing fairly well at present. Three of the 41 survivors of the operation for cancer may be regarded as representing five year cures. According to Walters, Gray and Priestley,[17] the death rate among patients who are operated on for gastric carcinoma and who survive for five years is essentially the same as that for the general population.

The most interesting case in this group is that of a man now 57 years old who was operated on eight years ago for a large adenocarcinoma involving the upper half of the stomach (fig. 3). The regional

17. Walters, W.; Gray, H. K., and Priestley, J. T.: Malignant Lesions of Stomach: Importance of Early Treatment and End Results, J. A. M. A. **117:** 1675 (Nov. 15) 1941.

lymph nodes removed with the operative specimen showed metastases; in addition, nests of tumor cells were noted in the lymphatics and the blood vessels. This patient is now in excellent health, carries on with his usual occupation, has returned to normal eating habits and maintains an excellent state of nutrition.

In the second case, a woman, now 71, has survived over six years after operation for a scirrhous adenocarcinoma involving the greater portion of the stomach. In this case the regional lymph nodes were not involved. She did well for four and one-half years after operation, whereupon typical macrocytic anemia developed. This has responded well to treatment.

In the third case, a man, now 64, is alive and well approximately five years after operation. In this case there were a fairly localized carcinoma of the antrum and pronounced thickening of the proximal gastric wall, which extended up to the esophagus. At operation this was interpreted as a mural extension of the carcinoma, and a total gastrectomy was performed. Subsequent microscopic study of the tissue showed that the thickening was the result of severe hypertrophic gastritis, which was coexistent with the carcinoma. The regional lymph nodes showed no metastases. The good result obtained in this case suggests that, other factors being equal, better results might well be obtained in many cases of the smaller gastric carcinomas with total rather than with the usual subtotal gastrectomy.

In general, the end results are essentially the same as those reported from many clinics for the entire series of gastric carcinomas treated by the usual methods. While the results are not brilliant, they seem to indicate that the operation is worth while in a sufficiently large number of cases to warrant continuation of its use. The small number of patients salvaged would most certainly be lost without treatment. Admittedly, in the case of patients who survived for only a few months the value of the procedure is questionable. However, when life is prolonged for a year or more, the respite from symptoms which usually occurs would seem to make the operation worth while. In following a group of patients with untreated carcinoma of the stomach, Cheever [18] found that only 9.2 per cent lived six months or more after the diagnosis was made, and in nearly 40 per cent the length of life from the time of onset of symptoms until the time of death was only six months or less. The distressing symptoms of patients who die of untreated gastric carcinoma during the natural course of the disease are, unfortunately, familiar to all, and for this reason alone heroic attempts at palliation are to be encouraged.

18. Cheever, D.: The Operative Curability of Carcinoma of the Stomach, Ann. Surg. **78**:332, 1923.

The results following total gastrectomy for benign lesions have been uniformly good (table 6). Our longest period of survival following this operation was eight and one-half years, in the case of a woman operated on for a large neurofibroma. There has been no evidence of recurrence of the neoplasm, which was one which recurs locally unless completely excised.

One of the 3 patients with gastric ulcer treated by this method has obtained an excellent result. He is entirely free from symptoms and is leading a normal life, four and one-half years after operation. The second patient is in only fair health, more than five and one-half years later. Extensive studies have revealed spontaneous hypoglycemia and macrocytic anemia as the only significant organic disorders, conditions which do not adequately explain his numerous and bizarre symptoms. The diagnosis by a psychiatric consultant is "malignant psychoneurosis"; the prognosis is regarded as poor, and institutionalization has been recommended. The third patient was operated on less than one year ago and appears to be doing well at present.

TABLE 6.—*Patients Living After Total Gastrectomy for Benign Lesions*

Lesion	No. of Patients	Period	Result
Gastric ulcer	1	5 yr. 7 mo.	Fair
Gastric ulcer	1	4 yr. 4 mo.	Excellent
Gastric ulcer	1	8 mo.	Good
Neurofibroma	1	8 yr. 4 mo.	Good

SUMMARY AND CONCLUSIONS

1. Sixty complete gastrectomies have been performed during the past nine years, with 14 deaths, or an operative mortality of 23.3 per cent. The lesions for which the operation was performed, with the number of patients, were as follows: carcinoma, 53; gastric ulcer, 4; lymphosarcoma, 2, and neurofibroma, 1.

2. General peritonitis was the most frequent cause of death, and the most common source of it was leakage at the site of the esophagojejunal anastomosis.

3. Of the 46 patients who survived the operation, 31 have subsequently died. In all instances death was due to recurrence of the malignant disease. The average duration of life in this group was ten and one-half months.

4. Eleven patients are still living after operation for carcinoma. Approximately one half of these were operated on too recently for evaluation of the result. Three patients may be classified as representing five year cures.

5. All the patients with benign lesions who survived operation are living and maintain a satisfactory state of nutrition.

6. In 2 patients the classic picture of pernicious anemia developed approximately five years after operation.

7. The technical details of the operation are discussed, and the worth of the procedure is considered.

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DISCUSSION

DR. HOWARD K. GRAY, Rochester, Minn.: When Dr. Ransom invited me to open the discussion of this interesting paper, he asked that I review the experience in the Mayo Clinic with removal of the entire stomach. The series begins with the first total gastrectomy performed by Dr. W. J. Mayo, in 1917, and, including the operations performed prior to Jan. 1, 1946, comprises 124 cases. The over-all hospital mortality rate for the series was 40.3 per cent. The hospital mortality rate for the 91 cases in which operation was performed in the period from 1940 to 1945, inclusive, was 33.0 per cent, and that for 1945, during which total gastrectomy was performed in 24 cases, was 16.6 per cent (4 deaths). It is interesting to observe the consistency of the over-all hospital mortality rates for the various large series of cases, as recorded in Dr. Ransom's paper, and to note the obvious fact that with experience and improvements in preoperative and postoperative care the mortality rate can, and has been, reduced appreciably.

It is widely accepted that the lesion which most often requires complete gastrectomy is carcinoma or lymphoblastoma involving the greater part of the stomach, in particular, the diffuse, "leather bottle" type of carcinoma, or linitis plastica. The statement, however, that smaller malignant neoplasms situated in the upper half or the upper third of the stomach are best treated with total gastrectomy is subject to question, for lesions in these areas occasionally lend themselves admirably to removal by the transthoracic route. The procedure does not impose any greater risk than total gastrectomy if performed by a surgeon familiar with both thoracic and gastric surgery. In fact, in the four year period from 1942 to 1945, inclusive, partial gastrectomy was performed at the Mayo Clinic in 29 cases, with 6 deaths in the hospital, a hospital mortality rate of 20.6 per cent.

The argument may be advanced that the transthoracic operations were done primarily for lesions involving the lower part of the esophagus, and secondarily the stomach, and that therefore the transthoracic approach was the only method indicated in these cases. As a matter of fact, in all 29 cases the roentgenologist interpreted the lesion as being located in the upper portion of the stomach and involving the cardia alone in 14 cases, the fundus in 4 cases and the cardia and the lower portion of the esophagus in only 11 cases. In 2 cases in which the lesion was situated in the cardia microscopic examination revealed a benign gastric ulcer, and in 1 case, a leiomyoma. In all 11 cases in which the roentgenologist observed encroachment on the esophagus the pathologist reported that the central ulcerative growth was located in the stomach and was diagnosed as adenocarcinoma; this would be presumptive evidence that the neoplastic lesion had originated in the stomach, with secondary infiltration into the esophagus. That a portion of the stomach may be preserved and normal esophagogastric continuity maintained are added factors in favor of transthoracic approach in selected cases.

A second argument against the transthoracic removal of a malignant lesion of the stomach is that adequate excision of lymph-node-bearing tissue is not possible with this method. Although retrograde involvement of lymph nodes occurs occasionally, it is not common; and, although the time elapsed since the first transthoracic resection has been insufficient to permit definite conclusions regarding the anticipated survival of these unfortunate patients, preliminary studies on the postoperative course have indicated that the survival rate will be as good as, if not better than, that in cases of total gastrectomy.

The third objection to transthoracic resection of the stomach for carcinoma arises from motor difficulties encountered occasionally incident to section of the vagus nerves in the course of the operation. It has been the experience of workers advocating resection of the vagus nerves for benign ulcerating lesion of the stomach that the atony of the gastric musculature and small bowel, with or without varying degrees of pylorospasm, is transient. A similar condition might be anticipated when the vagus nerves are sectioned in the course of a resection of the upper portion of the stomach with reestablishment of esophagogastric continuity.

As has been noted by practically all observers, disturbance of digestive function following total gastrectomy may be important. In a recent report on a patient who had survived eight years after total gastrectomy, Weir pointed out that the digestive functions of pepsin and hydrochloric acid must be taken over by the pancreatic and intestinal enzymes. Ivy showed that in gastrectomized animals the intake of meat may cause diarrhea and that increased amounts of meat, milk and bread are required to maintain normal weight. This observation is consistent with the clinical investigations of Wollaeger, Comfort, Weir and Osterberg (*Proc. Central Soc. Clin. Research* **18**:37, 1945), who showed in a study of intake and excretion recently made at the clinic on patients after partial gastrectomy that the loss of fat in the stool was above normal and of variable amount, and that the loss of nitrogen was occasionally increased. The secretion of hydrochloric acid aids in the absorption of calcium and iron. One would expect calcium metabolism to be disturbed in a patient who has undergone total gastrectomy. In Weir's patient there was no disturbance in calcium metabolism, as evidenced by absence of osteoporosis and by the normal content of calcium and phosphorus in the serum. Perhaps the most consistent complaint has been the inability to take more than small quantities of food and the occurrence of the "dumping syndrome," first described by Hertz. Patients with this disorder usually complain immediately after eating of nausea, weakness, pallor, palpitation, tachycardia, perspiration, lightheadedness and faintness. Although the cause of these symptoms is not readily apparent, they are probably due to a reflex effect of too great and too rapid distention of the jejunum by the ingested food. Total removal of the stomach would be presumed to produce a pronounced effect on hematopoiesis because of failure of elaboration of the intrinsic factor, and numerous reports have appeared of the development of pernicious anemia or pernicious-anemia-like syndromes after total gastrectomy.

It was interesting to note in Weir's case that only at the last examination of the patient was there any significant macrocytosis. Slight glossitis occurred at times, but it was only at this examination that any atrophy of the tongue was noted.

RECENT ADVANCES IN VASCULAR SURGERY

A Review of the Literature

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IN THE wake of every great war, notable advances appear in certain scientific fields. It was on the field of battle that Paré revived and developed the use of the ligature in the treatment of arterial injuries. During World War I, clinical and experimental vascular research reached new peaks through the work of Halsted and his pupils, Holman and Reid, and through the work of Matas, Makins, Sehrt, Tuffier, Key and many others. Similarly, in the past few years, enormous strides have been made in vascular surgery.

VASCULAR REPAIR

Blakemore, Lord and Stefko,[1] in their search for a nonsuture technic, modified the old Payr magnesium rings used for vascular anastomosis by the preparation of a vein graft with the ends of the vessel everted over vitallium tubes. Such a cylinder, lined by endothelium and with rigid ends, was designed to be inserted into the proximal and distal ends of an artery in which there is an aneurysm or a loss of continuity owing to injury. Although its use in the armed forces was on a smaller scale than anticipated, this technic of vein grafting has proved of value in selected cases. The main objection to the use of this technic has been occlusion by thrombosis. The projection of the lips of the tubes into the arterial lumen produces eddies in the blood flow, and this, together with the ballooning of the vein when it is subjected to arterial pressure, permits the formation of a clot. Controlled use of heparin and dicumarol

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1. Blakemore, A. H.; Lord, J. W., Jr., and Stefko, P. L.: The Severed Primary Artery in the War Wounded: A Nonsuture Method of Bridging Arterial Defects, Surgery **12**:488-508 (Sept.) 1942; Restoration in Blood Flow in Damaged Arteries: Further Studies on a Nonsuture Method of Blood Vessel Anastomosis, Ann. Surg. **117**:481-497 (April) 1943. Blakemore, A. H., and Lord, J. W., Jr.: A Nonsuture Method of Blood Vessel Anastomosis: Experimental and Clinical Study, J. A. M. A. **127**:685-691 (March 24) 1945; A Nonsuture Method of Blood Vessel Anastomosis: Experimental and Clinical Study, ibid. **127**:748-753 (March 31) 1945; A Nonsuture Method of Blood Vessel Anastomosis: Review of Experimental Study; Report of Clinical Cases, Ann. Surg. **121**:435-452 (April) 1945.

has reduced this source of criticism. It is conceivable that in large medical centers dealing with many instances of acute trauma, banks of preserved and refrigerated vein grafts may be of value. Recently, Mustard [2] reported on experiences with nonsuture methods in military units operating near the front lines. He indicated a preference for a plastic rigid tube rather than the vein graft, especially in cases in which a long defect in the artery had to be bridged. Clotting was prevented by administration of dicumarol. Smith [3] has employed caramelized dextrose plugs of a diameter slightly greater than the lumen of an artery to be anastomosed end to end. With the ends of the vessel approximated over this cylindric dilator, the task of suturing is said to be easier and any constriction is avoided.

THROMBOEMBOLISM

During the past few years, the most satisfactory method of treating venous thrombosis has been the subject of some disagreement. The outstanding proponents have alined themselves in three main camps. Ochsner and DeBakey [4] have perhaps led in enthusiasm for sympathetic block, as they have been convinced that the resulting vasodilatation prevents reflex vasospasm and the formation of an embolus. Unquestionably, considerable symptomatic relief is afforded by this procedure. A. W. Allen, Linton and Donaldson,[5] Homans,[6] and Linton [7] have championed ligation of the vein proximal to the thrombotic process. A number of cases in which even the inferior vena cava has been ligated in an effort to prevent pulmonary embolism have been reported by Atlas,[8] Buxton and others,[9] Collins and associates,[10] Gaston and Fol-

2. Mustard, W. T.: The Technic of Immediate Restoration of Vascular Continuity After Arterial Wounds: Indications and Results, Ann. Surg. **124**: 46-59 (July) 1946.

3. Smith, S.: A Soluble Rod as an Aid to Vascular Anastomosis: An Experimental Study, Arch. Surg. **41**:1004-1007 (Oct.) 1940; Studies in Experimental Vascular Surgery, Surgery **18**:627-643 (Nov.) 1945.

4. Ochsner, A., and DeBakey, M.: Therapy of Phlebothrombosis and Thrombophlebitis, Arch. Surg. **40**:208-231 (Feb.) 1940; Intravenous Clotting and Its Sequelae, Surgery **14**:679-690 (Nov.) 1943.

5. Allen, A. W.; Linton, R. R., and Donaldson, G. A.: Thrombosis and Embolism: Review of Two Hundred and Two Patients Treated by Femoral Vein Interruption, Ann. Surg. **118**:728-740 (Oct.) 1943.

6. Homans, J.: Deep Quiet Venous Thrombosis in Lower Limb: Preferred Levels for Interruption of Veins; Iliac Sector or Ligation, Surg., Gynec. & Obst. **79**:70-82 (July) 1944.

7. Linton, R. R.: Venous Interruption in Thrombo-Embolic Disease, editorial, Surgery **19**:434-436 (March) 1946.

8. Atlas, L. N.: Ligation of the Inferior Vena Cava: A Case Report, Ohio State M. J. **39**:917-918 (Oct.) 1943.

som,[11] Homans,[6] Kern and Berman,[12] Northway and Buxton,[13] and O'Neil,[14] and Moses [15] among others. Thrombectomy has been performed, in addition, in some cases. Still another method of treatment in which anticoagulant drugs are employed has been described by Barker and others,[16] Evans,[17] and de Takats and Fowler.[18] Prophylactic and therapeutic use of dicumarol, with the dose controlled by daily determination of the prothrombin time, has proved successful at the Mayo Clinic.

As a result of the efficacy of dicumarol, when preceded by the administration of heparin,[19] and antispasmodic drugs, embolectomy rarely is necessary in embolism of a peripheral artery. The operation, when done, now is more successful than it was before these anticoagulant drugs were available as an adjunct. Wetherell [20] has outlined a three phase treatment of arterial embolism which embodies a practical approach to the condition. Papaverine is first given and the site of the embolus localized. The administration of heparin and dicumarol is begun, and if the vaso-

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9. Buxton, R. W.; Farris, J. M.; Moyer, C. A., and Coller, F. A.: Surgical Treatment of Long-Standing Deep Phlebitis of the Leg: A Preliminary Report, Surgery **15**:749-756 (May) 1944.

10. Collins, C. G.; Jones, J. R., and Nelson, E. W.: Surgical Treatment of Pelvic Thrombophlebitis: Ligation of Inferior Vena Cava and Ovarian Veins; Preliminary Report, New Orleans M. & S. J. **95**:324-329 (Jan.) 1943.

11. Gaston, E. A., and Folsom, H.: Ligation of the Inferior Vena Cava for the Prevention of Pulmonary Embolism: A Report of Two Cases, New England J. Med. **233**:229-233 (Aug. 23) 1945.

12. Kern, H. M., and Berman, E.: Ligation of Inferior Vena Cava for Pneumonic Thrombophlebitis, Am. J. Surg. **69**:120-125 (July) 1945.

13. Northway, R. O., and Buxton, R. W.: Ligation of the Inferior Vena Cava, Surgery **18**:85-94 (July) 1945.

14. O'Neil, E. E.: Ligation of the Inferior Vena Cava in the Prevention and Treatment of Pulmonary Embolism, New England J. Med. **232**:641-646 (May 31) 1945.

15. Moses, W. R.: Ligation of the Inferior Vena Cava or Iliac Veins: A Report of Thirty-Six Operations, New England J. Med. **235**:1-7 (July 4) 1946.

16. Barker, N. W.; Cromer, H. E.; Hurn, M., and Waugh, J. M.: The Use of Dicumarol in the Prevention of Postoperative Thrombosis and Embolism with Special Reference to Dosage and Safe Administration, Surgery **17**:207-217 (Feb.) 1945. Barker, N. W.: Anticoagulant Therapy in Postoperative Thrombophlebitis and Pulmonary Embolism, Minnesota Med. **29**:778-782 (Aug.) 1946.

17. Evans, J. A.: The Combined Use of Heparin and Dicoumarin (3,3′ Methylenebis, 4-Hydroxycoumarin) in Thrombophlebitis and Pulmonary Embolism: Preliminary Report, Lahey Clin. Bull. **2**:248-256 (April) 1942.

18. de Takats, G., and Fowler, E. F.: The Problem of Thrombo-Embolism, Surgery **17**:153-177 (Feb.) 1945.

19. Murray, G.: Heparin in Surgical Treatment of Blood Vessels, Arch. Surg. **40**:307-325 (Feb.) 1940.

20. Wetherell, F. S.: Treatment of Arterial Embolism of the Extremities: A Three-Phase Division, New York State J. Med. **44**:35-42 (Jan. 1) 1944.

spasm has not been broken in one to two hours paravertebral block of the lumbar sympathetic ganglions is carried out. If this is not successful, embolectomy is performed with local anesthesia.

COLLATERAL CIRCULATION

In obstructive lesions of the vascular system such as those due to arterial disease, embolism, thrombosis, tumor or ligature, the integrity of the part depends on the efficiency of the collateral circulation. In 1933, Gage [21] introduced the use of sympathetic block to stimulate the formation of a collateral circulation and to avoid vasospasm in cases of aneurysm. Subsequently, sympathectomy has been used more successfully for this purpose. Up to the time of the recent war, there was considerable controversy as to the actual value of this procedure in cases of chronic arteriovenous fistula, which in itself was believed to be the greatest known stimulus to collateral circulation. Within the past two years there have been a number of reports by Linton and White,[22] Pugh,[23] Harbison,[24] Kirtley,[25] and Mason and Giddings [26] which indicate that sympathectomy has a definite beneficial influence in such cases, as it prevents vasospasm, increases the collateral circulation and lessens the danger of anaerobic infection. Recently, Deterling, Essex and Waugh [27] demonstrated experimentally on dogs, by arteriography and determination of the cutaneous temperature, that while arterial collateral circulation appears rapidly in cases of femoral arteriovenous fistula it may be further stimulated, even after six months or more, by sympathectomy. With such a procedure available, it may be possible to effect an early closure of such fistulas, thus avoiding the local and general

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21. Gage, M.: Mycotic Aneurysm of the Common Iliac Artery: Sympathetic Ganglion Block as an Aid in the Development of the Collateral Circulation in Arterial Aneurysm of Peripheral Arteries; Report of a Case, Tr. South. S. A. **46**:473-516, 1933.

22. Linton, R. R., and White, P. D.: Arteriovenous Fistula Between the Right Common Iliac Artery and the Inferior Vena Cava: Report of a Case of Its Occurrence Following an Operation for a Ruptured Intervertebral Disk with Cure by Operation, Arch. Surg. **50**:6-13 (Jan.) 1945.

23. Pugh, H. L.: Surgical Management of Vascular Trauma, Am. J. Surg. **68**:5-20 (April) 1945.

24. Harbison, S. P.: Experiences with Aneurysms in an Overseas General Hospital, Surg., Gynec. & Obst. **81**:128-137 (Aug.) 1945.

25. Kirtley, J. A.: Arterial Injuries in a Theatre of Operations, Ann. Surg. **122**:223-234 (Aug.) 1945.

26. Mason, J. M., III, and Giddings, W. P.: Experience with Lumbar Sympathetic Ganglionectomy for Wounds of Major Blood Vessels of the Lower Extremity, Surg., Gynec. & Obst. **81**: 169-176 (Aug.) 1945.

27. Deterling, R. A., Jr.; Essex, H. E., and Waugh, J. M.: Arteriovenous Fistula: Experimental Study of the Influence of the Sympathetic Nervous System on the Development of Collateral Circulation, Surg., Gynec. & Obst. **84**: 629-641 (April) 1947.

cardiovascular alterations which develop in time in the presence of such a lesion.[28]

ANEURYSM

Simple arterial aneurysms have been treated by a variety of chemical, mechanical and surgical procedures. Blakemore and King [29] have had success with an improved technic of electrothermic coagulation in cases of aortic aneurysm. In certain cases of peripheral aneurysm Blakemore has used an inlay vein graft and his vitallium tube nonsuture technic.[30] With the aneurysmal sac opened, the ends of the prepared venous segment are inserted into the arterial ostiums, and the wall of the sac imbricated over the graft to lend support. Mention should be made of the increasing use of permeable "cellophane" and other films to effect gradual closure of a vessel by virtue of the stenosing fibrosis evoked. This action on living tissues was demonstrated in 1939 by Page [31] when he obtained a pronounced fibrosis of the renal capsule following the application of "cellophane" to the kidneys in an experimental study of hypertension. Pearse [32] in 1940 extended its use to the vascular system by a series of experiments on the aortas of dogs. Subsequently, "cellophane" has been used to aid in the obliteration of the ductus arteriosus. Harrison and Chandy [33] reported the cure of a subclavian aneurysm by the occlusive action of such fibrosis. "Cellophane" bands had been placed about the vessel on either side of the aneurysmal sac. Poppe and de Oliveira [34] described the degree of reactivity of tissue to the various types of films which induce fibrosis and reported the successful application of polythene to a fusiform aneurysm of the thoracic aorta.

PORTAL HYPERTENSION

As a result of the excellent work of the spleen clinic at the Columbia-Presbyterian Medical Center in New York, there has been a greater

28. Mason, J. M.: Extreme Cardiac Decompensation Following Traumatic Arteriovenous Fistula of the Left Subclavian Vessels, Am. J. Surg. **20**:451-473 (May) 1933. Mason, J. M.; Graham, G. S., and Bush, J. D.: Early Cardiac Decompensation in Traumatic Arteriovenous Aneurysm, Ann. Surg. **107**:1029-1036 (June) 1938.

29. Blakemore, A. H., and King, B. G.: Electrothermic Coagulation of Aortic Aneurysms, J. A. M. A. **111**:1821-1827 (Nov. 12) 1938.

30. Blakemore, A. H.: Personal communication to the author.

31. Page, I. H.: A Method for Producing Persistent Hypertension by Cellophane, Science **89**:273-274 (March 24) 1939.

32. Pearse, H. E.: Experimental Studies on the Gradual Occlusion of Large Arteries, Ann. Surg. **112**:923-933 (Nov.) 1940.

33. Harrison, P. W., and Chandy, J.: A Subclavian Aneurysm Cured by Cellophane Fibrosis, Ann. Surg. **118**:478-481 (Sept.) 1943.

34. Poppe, J. K., and de Oliveira, H. R.: Treatment of Syphilitic Aneurysms by Cellophane Wrapping, J. Thoracic Surg. **15**:186-195 (June) 1946.

understanding of portal hypertension. Whipple's group has divided cases of portal hypertension into two groups: (1) cases of intrahepatic block, in which the obstruction is in the liver, and (2) cases of extrahepatic block, in which the obstruction is in the portal vein or one of its tributaries.[35] As a result of surgical experience, Blakemore and Lord[36] have demonstrated that the latter type of lesion is more amenable to operative intervention. In some cases there is congenital atresia of the portal vein or cavernous transformation, while thrombotic obstruction secondary to trauma or infection is present in other cases. The diagnosis generally is established by the presence of splenomegaly, anemia, leukopenia and thrombopenia and a history of hemorrhages from the stomach and the intestinal tract. When present, normal hepatic function will help distinguish extrahepatic block from intrahepatic block. At operation, the exact site of the obstruction is determined by direct examination or, in some cases, by the difference of venous pressures in the coronary, superior mesenteric and splenic veins. If the portal vein cannot be utilized, as in some cases of congenital lesions, an end to end splenorenal venous anastomosis may be employed. This shunting of portal blood into the systemic veins necessitates sacrifice of the spleen and left kidney and serves to shunt only 30 per cent or so of the portal blood. Consequently, in cases in which the portal pressure is two and a half to five times as great as it normally is (the normal pressure is 10 cm. of water), an end to side portacaval anastomosis may produce a swift regression of symptoms. As a result of successful experiments, it has been proposed that in cases in which such an increase in portal pressure is associated with massive ascites (usually cases of intrahepatic block) the proximal open end of the left ureter remaining after a splenorenal anastomosis should be sutured into the peritoneal space, thus offering a conduit for the ascitic fluid to drain by way of the bladder.

CONGENITAL CARDIOVASCULAR ANOMALIES

In the realm of thoracic surgery, the successful operative cure of certain congenital lesions of the heart and great vessels has been one of the outstanding achievements in medical science. Although there has not been any significant work on intracardiac surgery for valvular stenosis since the efforts of Cushing, Bernheim, Carrel, Graham and Cutler and their co-workers,[37] the war has made the heart a surgical organ. The literature contains reports of many cases in which

35. Whipple, A. O.: The Problem of Portal Hypertension in Relation to the Hepatosplenopathies, Ann. Surg. **122:** 449-475 (Oct.) 1945; Rationale of Portacaval Anastomosis, Bull. New York Acad. Med. **22:** 251-253 (May) 1946.

36. Blakemore, A. H., and Lord, J. W., Jr.: The Technic of Using Vitallium Tubes in Establishing Portacaval Shunts for Portal Hypertension, Ann. Surg. **122:** 476-489 (Oct.) 1945. Blakemore, A. H.: Portacaval Anastomosis: Report on Fourteen Cases, Bull. New York Acad. Med. **22:** 254-263 (May) 1946.

missiles have been removed successfully from the walls or chambers of the heart.[38] The recent introduction of an improved cardioscope by Harken and Glidden [39] once again widens the possible scope of surgical treatment.

Congenital malformations of the cardiovascular system often are associated with other anomalies, such as arachnodactyly, mongolism, spina bifida and cleft palate, which may serve in themselves to warn the physician to look for a lesion of the heart. Congenital cardiac defects are said to comprise 2 per cent of all cardiac lesions that become evident before the age of 12 years. The incidence of lesions of the aorta such as the presence of bicuspid valves and hypoplasia, coarctation and stenosis, is greater among males than it is among females, while the incidence of patent ductus arteriosus is greater among females.

At the meeting of the Minnesota State Medical Association in June 1947, R. E. Gross presented an interesting series of cases in which tracheal or esophageal obstruction was observed in infants as a result of anomalies of the aortic arch and its major branches. The compression in these instances resulted from the presence of a double aortic arch, from the innominate artery which originated adjacent to the left common carotid artery, or from an anomalous right subclavian artery which originated distal to the left subclavian artery. Symptomatic relief was accomplished by division of the anomalous vessel, or by displacement

37. Cushing, H., and Branch, J. R. B.: Experimental and Clinical Notes on Chronic Valvular Lesions in the Dog and Their Possible Relation to a Future Surgery of the Cardiac Valves, J. M. Research **17**:471-486 (Feb.) 1908. Bernheim, B. M.: Experimental Surgery of the Mitral Valve, Bull. Johns Hopkins Hosp. **20**:107-110 (April) 1909. Carrel, A., and Tuffier, T.: Etude anatomo-pathologique et expérimentale sur la chirurgie des orifices du coeur, Presse méd. **1**: 173-177 (March 4) 1914. Allen, D. S., and Graham, E. A.: Intracardiac Surgery: A New Method; Preliminary Report, J. A. M. A. **79**:1028-1030 (Sept. 23) 1922. Graham, E. A.: Recent Phases of Thoracic Surgery, ibid. **80**:1825-1831 (June 23) 1923. Cutler, E. C.; Levine, S. A., and Beck, C. S.: The Surgical Treatment of Mitral Stenosis: Experimental and Clinical Studies, Arch. Surg. **9**:689-821 (Nov.) 1924. Cutler, E. C., and Beck, C. S.: The Present Status of the Surgical Procedures in Chronic Valvular Disease of the Heart: Final Report of All Surgical Cases, ibid. **18**:403-416 (Jan.) 1929.

38. Harken, D. E.: Foreign Bodies In, and in Relation to, the Thoracic Blood Vessels and Heart: I. Techniques for Approaching and Removing Foreign Bodies from the Chambers of the Heart, Surg., Gynec. & Obst. **83**:117-125 (July) 1946. Harken, D. E., and Williams, A. C.: Foreign Bodies in and in Relation to the Thoracic Blood Vessels and Heart: Migratory Foreign Bodies Within the Blood Vascular System, Am. J. Surg. **72**:80-90 (July) 1946. Harken, D. E., and Zoll, P. M.: Foreign Bodies in and in Relation to the Thoracic Blood Vessels and Heart: III. Indications for the Removal of Intracardiac Foreign Bodies and the Behavior of the Heart During Manipulation, Am. Heart J. **32**:1-19 (July) 1946. Shapiro, R.: Intracardiac Foreign Body: Report of a Case with Recovery, ibid. **30**:88-91 (July) 1945.

39. Harken, D. E., and Glidden, E. M.: Experiments in Intracardiac Surgery: II. Intracardiac Visualization, J. Thoracic Surg. **12**:566-572 (Aug.) 1943.

of the vessel by fixation to adjacent structures when division of the vessel appeared hazardous.

Patent Ductus Arteriosus.—The ductus arteriosus serves a necessary function in the fetal circulation in joining the systemic and pulmonary circuits. Although originally noted by Galen,[40] it has been known as the ductus Botalli since its description by Botallus [41] in 1660. After birth, the channel undergoes involution as a result of physiologic and anatomic alterations associated with normal pulmonary function. Kennedy [42] in a study on guinea pigs and Barclay, Bancroft, Barron and Franklin [43] by the use of arteriography of fetal lambs delivered by cesarean section showed that functional closure of the ductus arteriosus may occur in as short a time as five minutes after birth. The anatomic closure is a slower process, but normally the tract has become a fibrous cord by the third week of extrauterine life. However, the vessel occasionally continues to persist. Christie [44] stated that while only 35 per cent of these vessels are closed by two weeks, only 1 per cent are patent after one year. Abbott [45] found 242 cases of patent ductus arteriosus in 1,000 cases of congenital heart disease. In these 1,000 cases, the incidence of patent ductus arteriosus was second only to that of intracardiac septal defects. As a result of the experimental work by Eppinger, Burwell and Gross,[46] considerable knowledge has been gained as to the disturbance of cardiovascular function in cases of patent ductus arteriosus. From studies on oxygen content of the whole blood, these authors showed that the direction of blood flow is typically from the aorta into the pulmonary artery, as described by Rokitansky [47] in 1852. Clinical evidence to support their work is the usual absence of cyanosis, aortic pressure being higher than the pulmonary pressure, the dilatation of the pulmonary artery, and the fact that vegetations in subacute bacterial endarteritis are most frequent on the pulmonary side of the

40. Galen, cited by Gilchrist.[50]

41. Botallus, L.: Opera omnia, medica et chirurgica, Lugd. Batavia, Joannis van Horne, 1660, p. 66.

42. Kennedy J. A.: A New Concept of the Cause of Patency of the Ductus Arteriosus, Am. J. M. Sc. **204**:570-573 (Oct.) 1942.

43. Barclay, A. E.; Barcroft, J.; Barron, D. H., and Franklin, K. J.: A Radiographic Demonstration of the Circulation Through the Heart in the Adult and in the Foetus, and the Identification of the Ductus Arteriosus, Brit. J. Radiol. **12**:505-517 (Sept.) 1939.

44. Christie, A.: Normal Closing Time of the Foramen Ovale and the Ductus Arteriosus: An Anatomic and Statistical Study, Am. J. Dis. Child. **40**:323-326 (Aug.) 1930.

45. Abbott, M. E.: Atlas of Congenital Cardiac Disease, New York, American Heart Association, 1936.

46. Eppinger, E. C.; Burwell, C. S., and Gross, R. E.: The Effects of the Patent Ductus Arteriosus on the Circulation, J. Clin. Investigation **20**: 127-143 (March) 1941.

47. Rokitansky, cited by Holman.[48]

ductus arteriosus. Some cases have been reported in which there was a reversed direction of blood flow, frequently a result of an associated congenital defect.[48] Although a patent ductus arteriosus represents an arteriovenous shunt, the effect on cardiac output differs from that of peripheral arteriovenous fistulas. In cases of the latter anomaly, there is as much as 100 per cent increase in the output of both ventricles. In the presence of ductus arteriosus, the output of the left ventricle may increase 75 per cent, but there is an associated decrease in that of the right ventricle.[46] However, a wide pulse pressure is found in both types of shunt, as is an increase in the total volume of circulating blood.

Certain diagnosis of patent ductus arteriosus is not always easy,[49] although it has been stated that in 70 per cent of the cases the diagnosis is made by the time the patients are 20 years of age.[50] There is often a history of "heart trouble" and poor development from early childhood, with an absence of cyanosis or clubbing of the digits. Examination should reveal a roaring machinery murmur with a frequent associated thrill, first described by Gibson [51] in 1898. The systolic phase of the murmur is generally accentuated, as is the pulmonic second sound. The area of greatest intensity of the murmur is in the second intercostal space to the left of the sternum. The murmur may be transmitted to the vessels of the neck. A narrow ductus arteriosus produces a high-pitched loud murmur, while with a wide ductus arteriosus there may be no murmur or a murmur of low intensity. Gerhardt's sign, a band of dulness to percussion along the left sternal border in the first, second and third interspaces, is rarely noted. Although the heart may be somewhat enlarged, especially the left auricle and ventricle, the electrocardiogram is generally normal. Stunting of growth and underdevelopment are the result of the shunting of a large proportion of the output of the left ventricle into the pulmonary circuit instead of into the peripheral systemic circulation. Roentgenographic examination often will reveal dilatation of the pulmonary artery and roentgenoscopy may disclose excessive hilar pulsation.[52]

Closure of this abnormal communication is the indicated treatment unless a marked degree of hypoplasia or stenosis of either great vessel is present. In such cases, a patent ductus arteriosus serves as a collateral

48. Holman, E.: Certain Types of Congenital Heart Disease Interpreted as Intracardiac Arteriovenous and Venoarterial Fistulae, Bull. Johns Hopkins Hosp. **36**:61-80 (Jan.) 1925.

49. Shapiro, M. J.: Patent Ductus Arteriosus, Journal-Lancet **64**:137-139 (May) 1944.

50. Gilchrist, A. R.: Patent Ductus Arteriosus and Its Surgical Treatment, Brit. Heart J. **7**:1-36 (Jan.) 1945.

51. Gibson, cited by Gilchrist.[50]

52. Hubeny, M. J.: Roentgen Diagnosis of Patent Ductus Arteriosus with Report of a Case Complicated by Presence of Saccular Aneurysm, Am. J. Roentgenol. **7**:23-26 (Jan.) 1920.

circulation. Ordinarily, however, severe complications result from such a communication. It has been estimated that from 25 to 30 per cent of patients who have this anomaly die of cardiac failure and that subacute bacterial endarteritis develops in 30 to 40 per cent of cases. The life expectancy has been said to be 25 to 35 years. Bullock and his associates,[53] reviewed 80 fatal cases and found that 14 per cent of the patients were dead by 15 years of age, 50 per cent were dead at the age of 30 years and 71 per cent were dead at 40 years. Even though the newer antibiotics are effective in treatment of endarteritis, the continued decline in morbidity and mortality in cases in which operation is performed makes this the treatment of choice.

Before the assembly of the Philadelphia Academy of Surgery in 1907, Munro [54] proposed surgical closure of the ductus arteriosus, but it was not to be attempted until thirty years later, when Strieder unsuccessfully operated in a case in which subacute bacterial endarteritis [55] was present. On Aug. 26, 1938, Gross [56] closed a ductus arteriosus successfully by ligation in continuity, a feat which was repeated shortly afterward in many parts of the world. It was not until 1940 that Touroff and Vesell [57] reported the successful ligation of a ductus arteriosus in the presence of endarteritis. Closure of the ductus has been effective in curing subacute bacterial endarteritis.[58] The operative technic has passed through various evolutions as recurrences were reported after simple ligation.[59] Gross [60] found the use of "cellophane" bands to

53. Bullock, L. T.; Jones, J. C., and Dolley, F. S.: The Diagnosis and the Effects of Ligation of the Patent Ductus Arteriosus: A Report of Eleven Cases, J. Pediat. **15:** 786-801 (Dec.) 1939.

54. Munro, J. C.: I. Ligation of the Ductus Arteriosus, Ann. Surg. **46:**335-338 (Sept.) 1907.

55. Graybiel, A.; Strieder, J. W., and Boyer, N. H.: An Attempt to Obliterate the Patent Ductus Arteriosus in a Patient with Subacute Bacterial Endarteritis, Am. Heart J. **15:** 621-624 (May) 1938.

56. Gross, R. E., and Hubbard, J. P.: Surgical Ligation of a Patent Ductus Arteriosus: Report of First Successful Case, J. A. M. A. **112:**729-731 (Feb. 25) 1939.

57. Touroff, A. S. W., and Vesell, H.: Subacute Streptococcus Viridans Endarteritis Complicating Patent Ductus Arteriosus: Recovery Following Surgical Treatment, J. A. M. A. **115:** 1270-1272 (Oct. 12) 1940.

58. Tubbs, O. S.: The Effect of Ligation on Infection of the Patent Ductus Arteriosus, Brit. J. Surg. **32:** 1-12 (July) 1944.

59. Gross, R. E.: A Surgical Approach for Ligation of a Patent Ductus Arteriosus, New England J. Med. **220:** 510-514 (March 23) 1939; Surgical Management of the Patent Ductus Arteriosus with Summary of Four Surgically Treated Cases, Ann. Surg. **110:**321-351 (Sept.) 1939; Surgical Therapy for the Patent Ductus Arteriosus, New York State J. Med. **43:** 1856-1858 (Oct. 1) 1943.

60. Gross, R. E.: Complete Surgical Division of the Patent Ductus Arteriosus: A Report of Fourteen Successful Cases, Surg., Gynec. & Obst. **78:** 36-43 (Jan.) 1944.

stimulate a fibrous stricture rather successful. Involvement of the recurrent laryngeal nerve by the fibrotic process has not proved to be a complication. Harper and Robinson [61] reported an interesting case in which "cellophane" was used in addition to the ligation. In this case, a recurrence of the lesion was cured by the fibrosis which developed as a result of the action of the "cellophane." Blalock [62] has isolated the vessel by transfixion sutures at each end and has successfully obliterated the channel by a cotton tape ligature. Since ligation and division of a vessel are to be preferred in vascular surgery to ligation in continuity, occlusion by modified Crile clamps, division of the vessel and a continuous suture of its ends have been advocated by Gross [60] as the most dependable means of preventing a recurrence. Up to July 1947 he had performed this procedure in 177 cases with but 4 deaths. None of these was due to hemorrhage. However, if the tissue is friable and if endarteritis has occurred recently, the operative risk of this procedure is high in most hands. Crafoord [63] has even clamped off the aorta during division and suturing of the ductus. Since penicillin has become available, the mortality rate associated with closure of an uncomplicated ductus arteriosus should be well under 5 per cent and no higher than 10 per cent in cases in which subacute bacterial endaritis is present. Before this drug was available, it was noted that closure of the ductus served to cure the endarteritis in many instances. The optimal time for operation is in childhood, since adults are more likely to have less cardiac reserve and frequently have an extremely short ductus, which makes the operation more hazardous.

Coarctation of the Aorta.—Ccarctation of the aorta was described as a clinical entity by Paris [64] in 1791. Subsequently, Bonnet [65] divided this anomaly into two types: (1) infantile and (2) adult. The former type is found in infants who have died of the stenosis within the first year of life. In this type, the atresia or constriction is diffuse and involves a large portion of the thoracic aorta. Severe associated anomalies frequently are present and, since the collateral channels are insufficient, death is inevitable. The adult type, which I shall consider, results from a congenital annular stenosis of the thoracic aorta at or near the entrance of the ductus arteriosus. In about 10 per cent of

61. Harper, F. R., and Robinson, M. E.: Occlusion of Infected Patent Ductus Arteriosus with Cellophane, Am. J. Surg. **64:** 294-296 (May) 1944.

62. Blalock, A.: Operative Closure of the Patent Ductus Arteriosus, Surg., Gynec. & Obst. **82:** 113-114 (Feb.) 1946.

63. Crafoord, C., and Nylin, G.: Congenital Coarctation of Aorta and Its Surgical Treatment, J. Thoracic Surg. **14:**347-361 (Oct.) 1945.

64. Paris: Rétrécissement considérable de l'aorte pectorale, J. de chir. **2:**107-110, 1791.

65. Bonnet, cited by Blumenthal and Davis.[107]

cases, one finds the ductus arteriosus patent.[66] The aortic obstruction may serve to impede the natural process of involution.

Authors have disagreed regarding the incidence of the adult type of coarctation. In a study of 1,000 cases of congenital defects of the heart, Abbott [45] found 142 cases of coarctation of the aorta. In 105 of the 142 cases, the coarctation was of the adult type. Fawcett [67] reported that 18 instances of coarctation were found in 22,316 cases in which necropsy was performed at Guy's Hospital in the years 1826 to 1902. Blackford [68] reported that 44 instances of this anomaly were disclosed by 68,300 necropsies, a ratio of approximately 1 to 1,550. Evans [69] found that the incidence of both infantile and adult forms of this anomaly was 0.13 per cent in a series of 19,217 cases in which necropsy was performed. The adult type occurred in a ratio of 1 case to 1,471 necropsies. Perlman [70] analyzed the results of routine medical examination of a large number of selectees for military service and found only 1 instance of coarctation among every 10,000 men who were 18 to 35 years of age.

It should be noted, however, that Abbott [71] found that the diagnosis of coarctation had not been made clinically in 86 per cent of a series of 200 cases, and King [72] in 1926 said that a clinical diagnosis of this anomaly had been made only four times in thirty-seven years at Johns Hopkins Hospital. In the past two decades, however, the clinical diagnosis has been made with increasing frequency.[73] Levine [74] has

66. Abbott, M. E.: Statistical Study and Historical Retrospect of Two Hundred Recorded Cases, with Autopsy, of Stenosis or Obliteration of the Descending Arch, Am. Heart J. **3**:392-421 (April) 1928.

67. Fawcett, J.: Coarctation of the Aorta as Illustrated by Cases from the Post-Mortem Records of Guy's Hospital from 1826-1902, Guy's Hosp. Rep. **44**: 1-19, 1905.

68. Blackford, L. M.: Coarctation of the Aorta, Arch. Int. Med. **41**:702-735 (May) 1928.

69. Evans, W.: Congenital Stenosis (Coarctation), Atresia, and Interruption of the Aortic Arch: A Study of Twenty-Eight Cases, Quart. J. Med. **2**:1-32 (Jan.) 1933.

70. Perlman, L.: Coarctation of the Aorta: Clinical and Roentgenologic Analysis of Thirteen Cases, Am. Heart J. **28**:24-38 (July) 1944.

71. Abbott, M. E.: Coarctation of the Aorta of the Adult Type: II. A Statistical Study and Historical Retrospect of Two Hundred Recorded Cases with Autopsy, of Stenosis or Obliteration of the Descending Arch in Subjects Above the Age of Two Years, Am. Heart J. **3**:574-618 (June) 1928; footnote 66.

72. King, J. T., Jr.: Stenosis of the Isthmus (Coarctation) of the Aorta and Its Diagnosis During Life: Report of Four Cases, Arch. Int. Med. **38**:69-95 (July) 1926.

73. Rhodes, P. H., and Durbin, E.: Coarctation of the Aorta in Childhood: Review of the Literature and Report of Three Cases, Am. J. Dis. Child. **64**:1073-1096 (Dec.) 1942.

74. Levine, S. A.: Clinical Heart Disease, Philadelphia, W. B. Saunders Company, 1940.

estimated that 0.1 per cent of the entire population has some degree of coarctation. Contrary to simple patent ductus arteriosus, coarctation is observed in males more frequently than it is in females, the ratio of males to females being about 4 to 1. It is interesting to note from Abbott's analysis that in 75 per cent of 200 cases the patients were males, they had an aortic lumen of less than 6 mm. at the site of coarctation, they died before the age of 40 years and they died of the coarctation or its direct cardiovascular complications.[66]

The alterations in cardiovascular function in cases of coarctation are significant and interesting. The early development of collateral channels often permits the patients to carry on more strenuous activities than would be anticipated from the degree of obstruction. Since the site of the coarctation is below the origin of the left subclavian artery in almost all cases, the accessory circulation is derived largely from anastomoses of (1) the superior intercostal with the first aortic intercostal artery, (2) the internal mammary with the epigastric and intercostal arteries and (3) the subscapular with the circumflex scapular artery. The position of the obstruction causes major changes in the dynamics of the circulation above and below.

The increase in the amount of blood that flows through the vessels of the upper extremities, the neck and the head is evidenced in some cases by an elevation of the basal metabolic rate. Grollman and Ferrigan [75] expressed the opinion that this is due to increased blood supply to the thyroid gland. Because of the redistribution of blood around a centrally situated block, the peripheral flow of blood may be greater than normal. An elevation in cutaneous temperature of the lower part of the body, as well as an elevation of rectal temperature, has been recorded by Stewart and his co-workers,[76] but unpublished studies performed in Roth's laboratory at the Mayo Clinic failed to confirm these findings. The effect of coarctation on renal function has been studied by many investigators, since the cause of the attendant hypertension has been attributed to either renal ischemia or simple mechanical obstruction. This has been perhaps the most disputed aspect of the condition. Friedman and his associates,[77] in 1941 by inulin and "diodrast" clearance studies found that the blood supply of the kidney was definitely decreased. They explained the normal rate of glomerular filtration on the basis of increased filtration pressure secondary to spasm of the efferent arterioles. This supported the results of an experimental study

75. Grollman, A., and Ferrigan, J. P. Jr.: Cardiac Output: Its Related Functions in a Case of Coarctation of the Aorta, Arch. Int. Med. **53**: 35-38 (Jan.) 1934.

76. Stewart, H. J.; Haskell, H. S., and Evans, W. F.: The Peripheral Blood Flow and Other Observations in Coarctation of the Aorta, Am. Heart J. **28**: 217-232 (Aug.) 1944.

77. Friedman M.; Selzer, A., and Rosenblum, H.: The Renal Blood Flow in Coarctation of the Aorta, J. Clin. Investigation **20**:107-111 (March) 1941.

on rats by Rytand [78]; namely, that renal hypertension may be caused by the ischemia. Woodbury and associates,[79] Steele,[80] Stewart and co-workers,[81] and others have pointed out that the narrow pulse pressure and high diastolic pressure in the lower extremities indicate a widespread arteriolar spasm and increased peripheral resistance compatible with renal hypertension. Microscopic examination of specimens of skin obtained from the arm and the leg of a patient, aged 34 years, who had coarctation and severe hypertension and who was observed at the Mayo Clinic, revealed severe hyperplasia of the walls of the arterioles, which was of a greater degree in the vessels of the leg than it was in the vessels of the arm; however, Graybiel and his associates [82] were unable to demonstrate such alterations in a group of 5 young patients who had mild hypertension. Blumgart and his co-workers [83] found a normal arteriolar pressure in the arms of 2 patients and suggested that hypertension was the result of the mechanical effects of the stenosis and the relatively small caliber of the collateral channels. Brotchner [84] reported 5 clinical cases and performed occlusion experiments on the aortas of animals to support the mechanical theory rather than the pressor theory. This problem seems closer to a solution as a result of the satisfactory drop in blood pressure seen in most cases after operative removal of the coarctation. Although the apparent role of the mechanical block has been elucidated, it must be remembered that most of the patients who have been operated on have been young. Perhaps the renal factor becomes increasingly important as the patient grows older. In the first case of coarctation in which resection was performed at the Mayo Clinic, the patient was a man, aged 34 years,

78. Rytand, D A.: The Renal Factor in Arterial Hypertension with Coarctation of the Aorta, J. Clin. Investigation **17**:391-399 (July) 1938; Pathogenesis of Arterial Hypertension in Coarctation of Aorta, Proc. Soc. Exper. Biol. & Med. **38**:10-11 (Feb.) 1938.

79. Woodbury, R. A.; Murphey, E. E., and Hamilton, W. F.: Blood Pressures in Aortic Coarctation: Study of Pulse Contours Taken by the Direct Method, Arch. Int. Med. **65**:752-762 (April) 1940.

80. Steele, J. M.: Evidence for General Distribution of Peripheral Resistance in Coarctation of the Aorta: Report of Three Cases, J. Clin. Investigation **20**: 473-480 (Sept.) 1941.

81. Stewart, H. J., and Bailey, R. L., Jr.: The Cardiac Output and Other Measurements of the Circulation in Coarctation of the Aorta, J. Clin. Investigation **20**:145-152 (March) 1941.

82. Graybiel A.; Allen, A. W., and White, P. D.: Histological Study of Arterioles of Muscle and Skin from Arm and Leg in Individuals with Coarctation of Aorta, J. Clin. Investigation **14**: 52-56 (Jan.) 1935.

83. Blumgart, H. L.; Lawrence, J. S., and Ernstene, A. C.: The Dynamics of the Circulation in Coarctation (Stenosis of the Isthmus) of the Aorta of the Adult Type: Relation to Essential Hypertension, Arch. Int. Med. **47**: 806-823 (May) 1931.

84. Brotchner, R. J.: Etiology of Hypertension Resulting from Coarctation of the Aorta, Arch. Path. **28**:676-696 (Nov.) 1939.

whose diastolic pressure remained higher than 90 mm. of mercury for a few weeks after operation. His systolic and diastolic pressures then declined, and six months after operation his brachial arterial pressure was within normal limits. Gross followed the pressures in 20 cases in which resection had been carried out, and noted satisfactory decrease in all but 1. In this case the anastomosis left a smaller lumen than desired. He noted that the decrease in blood pressure generally does not occur for ten to twelve days after operation.

It has been shown that while the circulation time is usually normal above the site of obstruction, there is a definite slowing distally. Cardiac output has been measured by Grollman and Ferrigan [75] (1934), Stewart and Bailey [81] (1941) and others. This has been found normal or only slightly increased when the heart was well compensated. As about 25 per cent of the deaths are due to cardiac decompensation, this must be ruled out in such studies. The electrocardiogram, while usually normal, will show a left axis deviation as the commonest abnormality. A negative T wave in lead III frequently is seen, with or without coving (Stewart and Bailey [81]). The characteristic changes of essential hypertension also are found.

The presence of this condition should be suspected in any youth who has hypertension and pronounced pulsation of the carotid arteries. Many patients will have signs of aortic regurgitation. Between 25 and 40 per cent of patients coming to necropsy have bicuspid aortic valves. The greatly dilated and tortuous intercostal arteries, first illustrated by Meckel [85] in 1827, may become evident by their pulsation and bruit. Occasionally, the vessels may be felt over the scapular region. As the degree of stenosis increases, the strength of the pulsations in the femoral arteries decreases until, in cases of marked occlusion, no distal pulses can be felt. Dock [86] emphasized the lag in femoral pulse behind the radial pulse and advised simultaneous palpation of the femoral and radial arteries. Auscultation of the thorax frequently will reveal a harsh blowing systolic murmur, which is heard best in the posterior interscapular area and is independent of the diastolic aortic precordial murmur heard when aortic insufficiency is present.

A number of significant roentgenologic signs of coarctation have been described.[87] Primary or direct signs are: (1) the absence of the aortic knob, normally visualized to the left of the fifth thoracic vertebra on a posteroanterior roentgenogram, and (2) a defect of 1 to 2 cm. in the aortic shadow as outlined in a left oblique roentgenogram. Secon-

85. Meckel, cited by Abbott.[45]

86. Dock, W.: The Recognition of Coarctation of the Aorta, J. A. M. A. **99**:2024-2025 (Dec. 10) 1932.

87. Perlman.[70] Ernstene, A. C., and Robins, S. A.: The Roentgenologic Diagnosis of Stenosis of the Descending Arch (Coarctation) of the Aorta, Am. J. Roentgenol. **25**:243-246 (Feb.) 1931. Fray, W. W.: The Roentgenologic Diagnosis of Coarctation of the Aorta (Adult Type), ibid. **24**:349-362 (Oct.) 1930.

dary or indirect signs are hypertrophy of the left ventricle (found in 75 per cent of the cases in Abbott's series [66]), dilatation of the ascending aorta and aortic arch proximal to the lesion (noted in 50 per cent of the cases in Abbott's series) and evidence of erosion of the ribs. The scalloping of the under surface of the ribs due to pressure erosion of the bone by the varicose intercostal vessels has been designated "Rösler's sign" [88] or "Dock's sign." [89]

The reasons for considering surgical resection of the coarctation and primary anastomosis of the aorta are many. The life expectancy is estimated to be 36 years. Death occurs from the effects of the coarctation in 77 per cent of cases, and in about the same percentage of cases death occurs before the age of 40 years. About 30 per cent of the patients die of decompensation and aortic insufficiency, 25 per cent die of rupture of the aorta and the remainder die of cerebral hemorrhage, sudden asystole, subacute bacterial endarteritis and rupture of an aneurysm, usually just proximal to the coarctation. The incidence of arteriosclerosis has been reported to be high in cases of coarctation.

As for indications for operation, one must consider the ability of the patient to withstand total occlusion of the aorta during the surgical procedure. Consequently, if the degree of coarctation is marked, the aorta may be occluded safely by virtue of the great collateral circulation. In complete atresia in which the entire aortic flow is diverted into other vessels, there is theoretically no time limit to the repair since no further obstruction results from clamping the aorta. In the 200 cases reported by Abbott,[66] complete atresia was present in 25 per cent, and narrowing to less than 6 mm. was present in an additional 50 per cent. Such patients should have little or no pulse or pressure in the femoral arteries. The severer the coarctation, the greater is the indication for operation. The optimal age for operation has been considered to be between 8 and 25 years.

The successful repair of this anomaly is truly a milestone in surgery and was the direct result of experimental and clinical research since 1938 by Gross [90] and Blalock [91] in America and Crafoord [63] in

88. Rösler, H.: Beiträge zur Lehre von den angeborenen Herzfehlern: IV. Untersuchungen an zwei Fällen von Isthmusstenose der Aorta, Wien. Arch. f. inn. Med. **15**:521-546, 1928.

89. Railsback, O. C., and Dock, W.: Erosion of the Ribs Due to Stenosis of the Isthmus (Coarctation) of the Aorta, Radiology **12**:58-61 (Jan.) 1929.

90. Gross, R. E., and Hufnagel, C. A.: Coarctation of Aorta: Experimental Studies Regarding Its Surgical Correction, New England J. Med. **233**: 287-293 (Sept. 6) 1945.

91. Blalock, A., and Park, E. A.: The Surgical Treatment of Experimental Coarctation (Atresia) of the Aorta, Ann. Surg. **119**:445-456 (March) 1944. Levy S. E., and Blalock, A.: Experimental Observations on the Effects of Connecting by Suture the Left Main Pulmonary Artery to the Systemic Circulation, J. Thoracic Surg. **8**:525-530 (June) 1939.

Sweden. In December 1944 Alexander [92] successfully performed thoracic aortectomy at the site of coarctation and aneurysm, but vascular continuity was not reestablished. In September 1945 Gross and Hufnagel [90] reported their experimental work and briefly mentioned 2 cases in which operation had been performed. In the first case, the patient unfortunately died of acute cardiac dilatation. Subsequently, Gross described these patients in greater detail [93] and has elucidated the surgical technic.[94] Crafoord and Nylin,[63] in October 1945, reported 2 cases in which resection and primary anastomosis were performed successfully by the Carrel technic. Up to February 1947, Crafoord had carried out resection in 15 cases of coarctation with 2 deaths. Up to July 1947, Gross had done resection in 22 cases, with but 2 deaths. Blalock, Clagett and others have now performed the operation successfully. Clagett has had occasion to anastomose the dilated left subclavian artery to the aorta distal to the stenosis in several cases, with or without resection of the coarctation.[95] Experimental work on various modifications of the technic is being carried out in many medical centers at the present time. As may be claimed in the case of surgical repair of a patent ductus arteriosus, a successful early operation in a case of uncomplicated coarctation may restore the patient to normal.

Pulmonary Stenosis or Atresia.—Stenosis or atresia of the pulmonary artery is another congenital anomaly which recently has been treated surgically. This anomaly was present in 205 of the 1,000 cases of congenital heart disease reported by Abbott.[45] When the anomaly is associated with a closed interventricular septum, there frequently is little cyanosis. However, there are relatively few cases without an interventricular septal defect. Atresia and stenosis of the pulmonary artery without septal defect each was present in about 10 per cent of the cases reported by Abbott. The remaining cases generally were classified as cases of the tetralogy of Fallot; that is, pulmonary stenosis, dextroposition of the aorta, defect of the interventricular septum and hypertrophy of the right ventricle. Although a simple defect of the ventricular septum (maladie de Roger) is a relatively common congenital defect and can be tolerated well, its association with hypoplasia of the pulmonary artery results in a serious clinical syndrome. Instead of the blood's flowing through the defect

92. Alexander, J., and Byron, F. X.: Aortectomy for Thoracic Aneurysm, J. A. M. A. **126**:1139-1145 (Dec. 30) 1944.

93. Gross R. E.: Surgical Correction for Coarctation of the Aorta, Surgery **18**:673-678 (Dec.) 1945.

94. Gross, R. E.: Technical Considerations in Surgical Therapy for Coarctation of the Aorta, Surgery **20**:1-8 (July) 1946.

95. Crafoord, C.: Personal communication to the author. Clagget, O. T.: Coarctation of the Aorta: Surgical Aspects, Proc. Staff Meet., Mayo Clin. **22**: 131-135 (April 2) 1947.

from the left ventricle to the right ventricle, the stenosis obstructs the pulmonary circulation sufficiently to reverse the direction of the flow in the ventricles. Aeration of the resultant small amount of circulating blood in the pulmonary circuit is not sufficient to prevent cyanosis.

The condition should be suspected if a child has clubbing of the digits, severe cyanosis and dyspnea on exertion. The physical examination of the thorax usually will reveal a harsh systolic murmur at the second to fourth intercostal spaces at the left border of the sternum. A vibrant thrill can be felt in about 30 per cent of cases. There is severe polycythemia. The value for the hemoglobin may become 26 Gm. per hundred cubic centimeters of blood and the erythrocyte count may be as high as 10,000,000 per cubic millimeter of blood. The electrocardiogram reveals a pronounced right axis deviation.

The surgical treatment of stenosis or atresia of the pulmonary artery has been primarly directed toward augmenting the flow of blood through the lungs and hence increasing the oxygenation of the circulating hemoglobin. Babcock [96] (1932) performed an end to end carotidojugular arteriovenous anastomosis in 1 case. The operation was performed to increase (1) the velocity of blood through the heart, (2) the cardiac output and return and (3) the degree of oxygen saturation of the hemoglobin in the pulmonary artery. It was hoped that a more frequent passage of blood with an elevated initial oxygen saturation through the lung would improve the condition. Unfortunately, the presence of widespread pulmonary tuberculosis in the patient obviated any hope for improvement.

On the basis of experimental work which showed the plausibility of anastomosis of systemic arteries to one of the pulmonary arteries, Blalock [97] (1945) devised an operation to increase the volume of blood which flows through the pulmonary circuit. In cases of atresia and stenosis, this is accomplished by an end to side anastomosis of the innominate or subclavian artery to the pulmonary artery. This in essence produces an artificial ductus arteriosus. This fact constitutes one of the chief objections to the operation, as one cardiovascular abnormality actually is substituted for another. The child may be subject to the complications of the ductus arteriosus, possibly with less ability to withstand the physiologic disturbances.

In cases of untreated pulmonary stenosis, the life expectancy is only 12½ years, with a maximum of about 25 years. Chief complications are cardiac failure, poor development and thrombosis. Operation aims

96. Babcock, W. W.: Newer Surgical Methods of Treating Diseases of the Vascular System, Am. J. Surg. **16**:401-407 (June) 1932.

97. Blalock, A., and Taussig, H. B.: The Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, J. A. M. A. **128**:189-202 (May 19) 1945.

primarily at increasing the pulmonary blood flow and, consequently, the oxygenation of the hemoglobin. The presence of 5 Gm. of reduced hemoglobin is sufficient to cause cyanosis. It has been notable that in cases in which operation has been performed, there has been a rapid fall in concentration of hemoglobin and in the erythrocyte count, with regression of the cyanosis. Blalock, since his first report in May 1945, has performed the operation in several hundred cases with good results. By now, many other surgeons have successfully performed the operation. With penicillin therapy available for the treatment of subacute bacterial endarteritis, and with the improvement in treatment of cardiac failure, it is probable that a substantial extension of more normal life has been attained for children who have been operated on for atresia or stenosis of the pulmonary artery.

NEW AND IMPROVED DIAGNOSTIC PROCEDURES

The exact diagnosis of congenital lesions of the heart and other vascular disorders has been advanced in the past several years by rapid developments in the field of arteriography and angiocardiography. In the early thirties these diagnostic procedures were mainly of academic interest because of the crude technics and the use of rather toxic concentrations of sodium iodide and colloidal thorium dioxide. However, with relatively innocuous contrast mediums now available for visualization of the heart and great vessels, a number of workers have developed safe technics.

Notable contributions to the visualization of the chambers of the heart and the great vessels have been those of Pérez de los Reyes, Castellanos and Pereiras [98] and Robb and Steinberg.[99] The abdominal aorta and its branches have been studied by Fariñas.[100] The accurate identification

98. Pérez de los Reyes, R.; Castellanos, A., and Pereiras, R.: Angiocardiography and Its Value, Am. Heart J. **25**:298-306 (March) 1943.

99. Robb, G. P., and Steinberg, I.: Visualization of the Chambers of the Heart, the Pulmonary Circulation, and the Great Blood Vessels in Man, Am. J. Roentgenol. **41**:1-17 (Jan.) 1939; A Practical Method of Visualization of the Chambers of the Heart, the Pulmonary Circulation, and the Great Blood Vessels in Man, J. Clin. Investigation **17**:507 (May 2) 1938; Visualization of the Chembers of the Heart, the Pulmonary Circulation, and the Great Blood Vessels in Heart Disease: Preliminary Observations, Am. J. Roentgenol. **42**:14-36 (July) 1939; Visualization of the Chambers of the Heart and the Thoracic Blood Vessels in Pulmonary Heart Disease: A Case Study, Ann. Int. Med. **13**:12-45 (July) 1939; Visualization of the Chambers of the Heart, the Pulmonary Circulation and the Great Blood Vessels in Man: Summary of Method and Results, J. A. M. A. **114**:474-480 (Feb. 10) 1940.

100. Fariñas, P. L.: A New Technique for the Arteriographic Examination of the Abdominal Aorta and Its Branches, Am. J. Roentgenol. **46**:641-645 (Nov.) 1941; Retrograde Arteriography in the Study of the Abdominal Aorta and Iliac Arteries, Surgery **18**:244-249 (Aug.) 1945; Retrograde Abdominal Aortography, Am. J. Roentgenol. **55**:448-451 (April) 1946.

of aneurysm, defects of the cardiac septum, coarctation of the aorta, tetralogy of Fallot and other congenital anomalies have been described recently by Robb and Steinberg,[99] Steinberg and associates,[101] Grishman and co-workers,[102] Sussman and co-workers,[103] Pérez de los Reyes and others,[98] Thompson,[104] Olney and Miller,[105] Stewart and associates,[106] Blumenthal and Davis[107] and others. Some of the contrast mediums that have been used for this purpose are "parabrodil," "iopax," "neo-iopax," "hippuran" N. N. R. and "diodrast" N. N. R. This last substance used in concentrations of 70 per cent has been most successful in the hands of American workers. The use of single roentgenograms timed for passage of the medium through the pulmonary circuit and through the left side of the heart and the aorta has been improved by the use of rapid multiple exposures (Sussman and his associates[103]) or cineroentgenography by which the course of the medium from the time of its injection may be followed continuously on the roentgenoscopic screen and photographed with the cinécamera (Stewart and his co-workers[106]). Electrokymography and catheterization of the chambers of the heart and great vessels have added much information as to the physiologic alterations resulting from these cardiovascular anomalies. As knowledge of congenital disorders is increased by such studies, one may expect the surgical treatment of cardiovascular disorders to continue to advance.

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101. Steinberg, I.; Robb, G. P., and Roche, U. J.: Differential Diagnosis of Mediastinal Tumor and Aortic Aneurysm: Value of Contrast Cardiovascular Visualization, New York State J. Med. **40**:1168-1177 (Aug. 1) 1940.

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103. Sussman, M. L.; Grishman, A., and Steinberg, M. F.: Newer Concepts in the Diagnosis of Congenital Heart Disease, Am. J. Dis. Child. **65**:922-936 (June) 1943.

104. Thompson, S. A.: Differential Diagnosis by Means of Intravenous Contrast Medium of Two Cases Simulating Aneurysm of the Pulmonary Artery, Am. J. Roentgenol. **46**:646-649 (Nov.) 1941.

105. Olney, M. B., and Miller, E. R.: Use of Intravenous Cardiography in the Study of Congenital Heart Disease with Cyanosis, Clinics **3**:235-244 (June) 1944.

106. Stewart, W. H.; Breimer, C. W., and Maier, H. C.: Cineroentgenographic Diagnosis of Congenital and Acquired Heart Disease, Am. J. Roentgenol. **46**: 636-640 (Nov.) 1941.

107. Blumenthal, S., and Davis, D. B.: Coarctation of the Aorta in Childhood: Report of Two Cases in Which the Diagnosis Was Confirmed by the Intravenous Injection of Diodrast, Am. J. Dis. Child. **62**:1224-1232 (Dec.) 1941.

OSTEOTOMY IN TREATMENT OF FRACTURES OF THE HIP

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MOST surgeons concede that the average case of intracapsular fracture of the neck of the femur still represents a major, and often irretrievable, disaster. Internal fixation of the fresh fracture and various methods of restoration of stability in cases with nonunion have been great advances. The younger group of patients, unfortunately small, usually does well; but, in all fairness, one must admit a high percentage of bad results in the run of cases. The causes of failure in the treatment of fresh fractures of the neck of the femur are well known; they include: (1) inadequate reduction and pinning; (2) degenerated bony structure, which in the aged will not support internal fixation; (3) late aseptic necrosis (or fragmentation) of the head of the femur; (4) degenerative arthritis, with or without bony union, and (5) too early weight bearing on a bad mechanical line subject to shearing force.

A recent personal poll of thirty leading orthopedic surgeons showed that there is still a wide divergence of opinion regarding the handling of both fresh and old fractures of the neck of the femur. With the omission of all cases but those of one year survival, the percentage in which bony union was obtained ranged from 60 to 90. As expected, some of the lower percentages were obtained among derelicts by surgeons working on charity services of large city hospitals. On the other hand, Henderson,[1] Meyerding[1] and Ghormley,[1] of the Mayo Clinic, reported bony union in 80 to 90 per cent of cases, modestly ascribing their high percentage of success to the fact that their patients of this type were largely vigorous farm folk living within 50 to 100 miles (8 to 16 kilometers) of Rochester, Minn. I hope that the reader bears in mind that I work in a large city, for my percentage of cases with satisfactory bony union is not more than 65.

Whatever the cause, all the surgeons questioned had seen many bad results in cases of intracapsular fracture of the neck of the femur. Practically all stated that they use some form of reconstruction operation, generally the Colonna or Brackett type, at least with the younger or more vigorous subjects, reserving osteotomy for the older group. This personal survey, as well as the literature of the past few years, shows

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1. Personal communication to the author, 1946.

that an increasing number of the leading surgeons of England and America perform osteotomy for all old fractures of the hip to correct bad results, whether due to malunion, nonunion or degenerative arthritis. Frank Dickson,[1] Leadbetter,[2] Wallace Cole,[1] Kellogg Speed,[3] J. S. Speed (Memphis),[4] George Bennett,[1] Hermann,[5] Barney Owen,[1] and McMurray,[6] of England, are a few who now use osteotomy as the treatment of choice in cases of old ununited fracture. Reich [7] and Magnuson [8] have used osteotomy with excellent results. Cole [1] and Murphy [9] have employed this method instead of primary pinning, while McMurray [6] uses it exclusively with both fresh and old intracapsular fractures. A few, though not the majority, reported the use of pins to hold the fragments after osteotomy. High osteotomy is more popular because of the greater chance of bony union in the original fracture and because internal fixation of the fragments is almost obligatory with the Schanz, or low, osteotomy.

All of the well known reconstruction operations of the hip were great contributions. Diagrammatically all can be made to look simple and efficient. In actual practice others, as well as myself, have found it necessary to use these procedures only in selected cases, because of conditions present at the site of fracture or because of the condition of the patient. Such procedures as the bone peg operation or the Brackett, Whitman or Colonna reconstruction are all formidable as to risk and are difficult of execution. J. S. Speed stated that only about 60 per cent of fairly good results are obtained with these large procedures even in selected cases and that 25 per cent of the favorable results are later vitiated by degenerative arthritis, causing painful and restricted movement of the hip. Against the net 45 per cent of satisfactory results from reconstruction operations performed only on patients who are good

2. Leadbetter, G. W.: Cervical-Axial Osteotomy of the Femur: Preliminary Report, J. Bone & Joint Surg. **26**:713-720 (Oct.) 1944.

3. Speed, K.: Treatment of Postoperative Infections Following Internal Fixation for Fracture of the Neck of the Femur, Tr. West. S. A. **52**:567-582, 1945; Subtrochanteric Osteotomy for Ununited Fracture of the Neck of the Femur, Ann. Surg. **124**:576-585 (Sept.) 1946.

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5. Hermann, O. J.: The McMurray Osteotomy for Nonunited Hip Fractures, New England J. Med. **232**:186-189 (Feb. 15) 1945.

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7. Reich, R. S.: Ununited Fracture of the Neck of the Femur Treated by High Oblique Osteotomy, J. Bone & Joint Surg. **23**:141-158 (Jan.) 1941.

8. Magnuson, P. R.: Fractures (Modified Brackett), Philadelphia, J. B. Lippincott Company, 1933.

9. Murphy, F. G.: Subtrochanteric Osteotomy for Fresh Fracture of the Neck of the Femur, S. Clin. North America **23**:211-220 (Feb.) 1943.

risks, most men reported about 80 per cent of good results with osteotomy as used on all types of patients, and bony union was achieved in about half, 50 per cent. The only procedure showing comparable results is the rarely indicated bone peg operation.

The advantages of osteotomy, presented so ably before this society by Kellogg Speed, are as follows:

1. It is a simple procedure, suitable to practically all age groups.

2. Aseptic necrosis of the head of the femur and degenerative arthritis have not been contraindications.

3. A good weight-bearing line, without shearing force, with or without bony union is achieved. Properly executed, a strong, stable hip is the probable result in the average case.

4. Revascularization of the head of the femur which has already undergone partial aseptic necrosis is not unusual.

5. About 80 per cent of good results can be expected, with bony union in at least 50 per cent. With proper technic, the percentage of bony union can be improved.

6. Few late degenerative changes have been noted after successful osteotomy.

7. Normal leverage of the gluteal and psoas muscles is preserved, making for stability of the hip.

8. Osteotomy is useful in treatment of malum coxae senilis.

9. The period of immobilization and non-weight-bearing is short. Objections to the spica cast are minimized by active muscular exercises and proper general management while the patient is in the cast. Henderson still uses a spica cast after internal fixation of fresh fractures. I agree with Dickson, Henderson and others, who feel that the disadvantages of casts are overrated. The rigid, twisted, hyperextended leg in the Whitman cast often caused stiffness of joints. After osteotomy the leg is in the neutral position with the knee slightly bent, and the cast is worn for only eight weeks.

TECHNIC OF OSTEOTOMY

During the past few years many fine discussions on high osteotomy have appeared in the literature. In each instance, the technic of the operation is dismissed with the statement that a high osteotomy at the proper point was made, followed by inward displacement of the shaft of the femur. It is true that the procedure is simple and a fair number of good results can be obtained with even a poorly performed osteotomy. Through a study of the factors involved in several poor results, a personally satisfactory technic has been evolved. On the other hand, important points have been discovered accidentally by observing the reasons for unusually successful results in 2 cases.

Before operation, roentgenograms are made on the operating table with the leg under manual traction. The line of osteotomy is then determined. A point as near as possible to the base of the greater trochanter is selected which will still allow the line of osteotomy to pass upward and inward to a level through or above the lesser trochanter. The higher the line of osteotomy can be made, the broader the base of the cancellous bone that can be obtained and the better the rotation of the head. Thus, more of the old fracture line can be freshened and brought into contact with the lower osteotomy fragment. To prevent knock knee, a certain amount of obliquity in the osteotomy is necessary to allow about 20 degrees of abduction and still have contact of the shaft with all three fragments. The greater the obliquity of the osteotomy, the more abduction is required for solid contact. Since not more than 20 degrees of abduction is desirable, the direction of the osteotome must be carefully guided. The high osteotomy with a certain amount of obliquity provides a broad base of cancellous, very highly osteogenic, bone at the upper end of the shaft. Proof of the reparative quality of bone in this area is shown by the fact that nonunion of intertrochanteric fractures is unknown. Before osteotomy is done, the periosteum must be stripped from the whole circumference of the upper end of the shaft through a vertical incision below the greater trochanter. The periosteum should be stripped clear for 3 or 4 inches (7.5 or 10 cm.) down on the shaft and as high as possible toward the trochanter and neck. The sheet of periosteum must be kept intact anteriorly and posteriorly. This maneuver is one of the critical points in performing successful osteotomy, because after the bone is cut through and the shaft displaced inwardly the periosteal connections between the shaft and the severed trochanter allow the trochanter also to be drawn snugly against the head and better contact against the shaft is also maintained. The three fragments can now be manually impacted in the desired position. Union is more assured, and internal fixation with pins to prevent separation of fragments is obviated. After the periosteum is separated and retracted anteriorly and posteriorly, osteotomy is performed on the predetermined line, using an osteotome slightly narrower than the shaft. The osteotome cuts through the periosteum on the medial aspect. At times it may be difficult to preserve both the anterior and the posterior periosteal strip, but any retained connection is valuable. An attempt is now made to rotate the head of the femur with a blunt elevator so that the old fractured surface faces somewhat downward. The shaft is displaced inward, using the osteotome as a combination lever and shoehorn. Often the upper inner point of the shaft, impinging against the lower edge of the head of the femur, can be made to aid in further rotating the head, so that more of the old fracture line can be brought into contact with the shaft. In this way union is more apt to be obtained; more new bone is deposited in the line of weight bearing, and the head is in a better position to receive weight bearing should bony union not be achieved. The portion of the head lying directly above the displaced shaft and as much of its old fractured surface as possible are now freshened with the osteotome, and pieces of bone from the osteotomized margins of the trochanter and shaft are forced into or around the old fracture area. Before closure of the wound, a roentgenogram is made to be sure the shaft has been displaced sufficiently inward and the inner margin impacted solidly against and beneath the lower margin of the head.

A double spica cast to the toes of the affected leg and the knee of the good leg is applied. The body portion of the cast need embrace only the pelvic region and can be cut down in front to a point below the level of the navel. After soreness from the operation has subsided, the patient is taught to contract actively all

muscle groups systematically, exercising five minutes of each waking hour. At the end of six weeks the cast is bivalved and more vigorous exercises are permitted. The entire cast is removed at the end of eight weeks, and after a few more days of exercises in bed the patient is started in a walker or on crutches, with gradually increasing weight bearing. From this point progress will vary with each patient, but all are encouraged to abandon walking aids as soon as possible.

COMMENT ON PERSONAL CASES

This report is based on the following personal experience: (1) osteotomy for old intracapsular fractures of the hip, 19 cases; (2) osteotomy for fresh intracapsular fractures, 2 cases, on which it is too early to report, and (3) osteotomy for malum coxae senilis without fracture, 4 cases.

A statistical study of these cases would be worthless and misleading. There were a number of bad results among the earlier cases. With a better mechanical and physiologic conception of the problem, the results have been more satisfactory. This series of cases is too small for dogmatic conclusions, but the impression gained is that fairly good restoration of function, usually with bony union, can be expected with osteotomy properly performed.

Malum coxae senilis is a form of degeneration in the head of the femur, probably due to partial loss of blood supply. Observing revascularization in a partially dead head of the femur following osteotomy for nonunion, I decided to try this procedure for malum coxae senilis. The only variation in technic is that the line of osteotomy is slightly more oblique and the inner margin of the shaft is displaced inward, always beneath the lower margin of the acetabulum. One patient has complete relief at the time of this report, four years after operation; the condition of 1 is improved, and that of the other 2 is not improved. These results are not spectacular, but the intention is to use the method in a larger series. It must be admitted that my own experience with other operations for this condition have been disappointing. The Australian procedure, consisting of making multiple drill holes through the trochanter into the head to encourage a new blood supply, has not achieved its objective in my hands but it suggested the use of osteotomy.

OSTEOTOMY IN TREATMENT OF FRESH FRACTURES

Since McMurray's report, about ten years ago, several surgeons have begun to use osteotomy for fresh fractures of the neck of the femur. Murphy [9] reported 10 cases, and Wallace Cole [1] stated that the method should be conceded a greater place in the treatment of this fracture. Whether internal fixation will be abandoned in favor of this procedure will be determined by more experience. The greater danger of infection and fragmentation of the head, as well as the longer period of non-weight-

bearing and the higher percentage of cases of degenerative arthritis are factors arguing against internal fixation. Points in favor of osteotomy are:

1. Complete valgus position and elimination of the shearing angle are achieved.

2. Better vascularization of the head with less danger of late arthritis and septic necrosis can be expected.

3. Osteotomy is technically easier in cases of fresh fractures than in cases of old ones because the shaft can be displaced inward and the head rotated more easily. The line of fracture is more nearly horizontal than vertical, completely eliminating the shearing angle. With the technic previously described, the continuity of periosteum and the pull of the common muscles attached to the osteotomized fragments tend to produce snug apposition of all three fragments without internal fixation.

4. Instead of the twisted, hyperextended position necessary with the old Whitman method, a comfortable cast is applied with the knee slightly bent, and the danger of subsequent stiffness of joints is kept at a minimum.

5. The results so far reported have been good. The average shortening has been about ½ inch (1.27 cm.), and motion of the hip joint, with the exception of full adduction, has been satisfactory. My own cases are too recent for final report, but it is my intention to continue the use of the method.

SUMMARY AND CONCLUSIONS

My technic for osteotomy is described.

Osteotomy seems to be the safest and best procedure for all old fractures of the hip.

There are no contraindications to osteotomy referable to the condition or the position of the fragments.

Osteotomy is useful in many other conditions of the hip, such as malum coxae senilis.

Osteotomy may partially or completely supplant internal fixation in the treatment of fresh intracapsular fractures of the hip.

902 Carew Tower.

DISCUSSION

DR. KELLOGG SPEED, Chicago: Is the problem of recent or old fracture of the hip solved? As Dr. Asbury stated, there are still unsatisfactory results. Here, I hear that good results are obtained in 86 per cent of patients after fracture but that the percentage after ununited fracture is much lower.

Certainly, inadequate reduction at the primary treatment is often at fault. In some instances, complete reduction by manipulation, either with or without skeletal traction and use of a fracture table, cannot be obtained. This failure leads either

to open reduction, which may be undesirable, or to acceptance by the surgeon of a fairly satisfactory incomplete reduction as a compromise.

The other points mentioned in this paper are well taken, especially that of late aseptic necrosis of the head of the femur, which may occur proximal to the area of union with the diaphysis, depending on incomplete revascularization of the head, as a result of manipulation or fixation or of too short a period of freedom from primary weight bearing. This late necrosis is an important complication. It may be the result of anoxia of the bone deprived of adequate circulation, aided by mechanical pressure, and comes on up to five years or more after the healing across the fractured plane. Its occurrence is unpredictable during the early course of the healing, even with roentgenologic control from the start.

For that reason, subtrochanteric osteotomy may become the primary treatment of choice. It is a way of sidetracking the pinning procedure and the long convalescence of bony healing without weight bearing. Finally, it is possible that revascularization of the head will be obtained in a higher percentage of cases after osteotomy. Time and trial will tell.

For morbus coxae senilis, with its narrowed and permanently changed, painful hip joint, headed by nature toward final stiffening, I prefer to use arthrodesis, which does away with pain, leg shortening and axial change and seems to offer adequate support for the relatively few years of life remaining to the average patient.

The problem of fracture still remains unsolved.

TREATMENT OF LOCALIZED INFECTIONS WITH PENICILLIN INFILTRATION

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THIS report deals with regional infiltration with penicillin, a method of therapy that has demonstrated its value in localized infections.

Florey [1] in his original 15 cases in which treatment was with penicillin suggested the possibilities of local application of penicillin. Fraser [2] and Flippen [3] injected penicillin into the cavities of soft tissue abscesses after aspiration of the purulent exudate. Several writers [4] have recommended the topical use of penicillin in the form of creams or solutions. Cutler and Sandusky [5] advocated a combination of penicillin powder and lyophilized human plasma. There are many reports [6] of the use of penicillin in combination with surgical débridement and its instillation into closed cavities. Peck [7] presented 15 cases in which penicillin solution was injected directly into the necrotic tissues or

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6. Dawson, M. H., and Hobby, G. L.: The Clinical Use of Penicillin: Observation in One Hundred Cases, J. A. M. A. **124**:611-622 (March 4) 1944. Lockwood, J. S.; White, W. L., and Murphy, F. D.: The Use of Penicillin in Surgical Infections, Ann. Surg. **120**:311-349, 1944. Robertson, I. M.: Penicillin in Bone Infections, Brit. M. J. **1**:519-521, 1944. Mowlem, R.: Surgery and Penicillin in Mandibular Infections, ibid. **1**:517-519, 1944. Fisher, A. M.: The Therapeutic Value of Penicillin Applied Locally, Based on Experience with the Crude Material in a Variety of Infections, Bull. Johns Hopkins Hosp. **76**: 134-153, 1945.

7. Peck, F. B.: Penicillin with Special Reference to Its Use in Infections Complicating Diabetes, Am. J. M. Sc. **208**:581-596, 1944.

sinuses of infected areas in diabetic patients with good results. He utilized a solution of penicillin in isotonic sodium chloride in a concentration of 100 to 1,000 units per cubic centimeter. These injections were repeated as often as every three hours. Rose and Hurwitz [8] reported 24 cases in which treatment was by daily injection in three or four sites at the margin of tenderness and toward the center of infection. Their rationale in this approach was an attempt to reenforce the natural barrier against infection set up by the host. Solutions of penicillin in concentrations up to 60,000 units per cubic centimeter were used without difficulty. The results were strikingly good. In the present series of cases localized infections were encompassed by a penicillin solution infiltrated entirely around the lesions, including the base, by means of multiple injections.

The effects of these injections in this series of cases were similar to those recorded by Rose and Hurwitz. The first infiltration was always moderately painful, but the subsequent ones were less so. The amount of pain depended on the care and slowness with which the infiltration was made. Pain from the infection itself disappeared a few minutes after the infiltration was made, however, and the lesion usually remained painless for many hours afterward. When pain did return, it was of less intensity than prior to the treatment. In all cases the erythematous area changed from a fiery to a dull red with a tinge of cyanosis. This cyanosis persisted long after the infection had been eradicated. The area of tenderness rapidly receded, and in cases in which there had been tender regional lymph nodes that tenderness also disappeared.

In a few cases in which pus had already formed and was near the surface, spontaneous evacuation occurred despite treatment. In 1 patient a small incision was made to evacuate the pus. In most instances healing occurred with resorption of pus and resolution of indurated tissues. No toxic reaction or sloughing of tissues was noted. Avoidance of disfiguring scars and of long hospitalization was extremely gratifying. Nevertheless, sound surgical judgment must be exercised in the selection and treatment of these patients.

TECHNIC OF INJECTION

A solution of penicillin in isotonic sodium chloride was made with 10,000 to 50,000 units of penicillin per cubic centimeter. The desired volume of this solution was combined with an equal volume of 1 per cent procaine hydrochloride just before injection. The infiltration was performed with a no. 22 needle of appropriate length, a single needle being used for each treatment. The entire lesion was then surrounded

8. Rose, D., and Hurwitz, D.: The Regional Injection of Penicillin in Local Infections, New England J. Med. **234**:291-296, 1946.

with penicillin solution at the outer margin of erythema or edema, two or more points of entry being used for the injections. Before the infiltration the area was cleansed with a mercurial antiseptic and 70 per cent alcohol or alcohol alone.

Injections were made once a day. The dose of penicillin as well as the volume of solution was varied according to type, location and size of the involved area. Subsequent injections were made as indicated. As much as 200,000 units of penicillin and as large a volume of solution as 50 cc. were used in some of the cases. The rationale for the large doses was the apparent effectiveness of penicillin when massive doses are used even against such nonsusceptible organisms as Escherichia coli. As far as possible, treatment was limited to local infiltration.

RESULTS

The present series comprise 12 patients, 6 treated as outpatients and 6 as inpatients. The former group consists of 3 patients with carbuncles and 3 with furuncles; the latter of 2 patients with carbuncles and 4 with cellulitis. The table is a summary of the cases in which treatment was given.

Two of the cases are presented in detail to illustrate the method and the results of such treatment.

REPORT OF CASES

CASE 1.—R. M., a 67 year old white woman with a known hypertensive history of ten years, was admitted with an inadequately incised carbuncle on the back of the neck. The patient noted a boil at this site about one week prior to admission. This lesion progressively increased in size and in painfulness.

Physical examination revealed a toxic, somewhat delirious elderly woman with a temperature of 100.8 F., a pulse rate of 66 and a respiratory rate of 30. Blood pressure was 212 systolic and 102 diastolic. On the back of the neck was a large carbuncle measuring 5 by 5 cm. with pronounced swelling, erythema and tenderness. In the center of this mass was a small cruciate incision draining seropurulent material. Surrounding this were several small necrotic heads. Occipital nodes were enlarged and tender. As movement was extremely painful, the head was held rigidly in a slightly flexed position.

Laboratory studies revealed a hemoglobin value of 13 Gm., 18,500 white blood cells and normal urine free of sugar.

Penicillin, 30,000 units immediately and 20,000 units every three hours intramuscularly, was given and hot packs were applied over the lesion. After four hours the temperature had risen to 102.6 F. (rectally). It was decided to try local infiltration of penicillin. Therefore 100,000 units in 20 cc. was used to infiltrate the lesion in its entirety at the outer margin of erythema and induration. There was considerable pain associated with the infiltration in spite of 16 mg. of morphine given one-half hour before the procedure. However, shortly after the infiltration the pain was gone. The following day she no longer had any pain from the carbuncle. The lesion was a dull, cyanotic red, and the area of tenderness had diminished slightly. This method of treatment was continued daily for eleven days.

Summary of Cases in Which There Was Treatment of Localized Infections with Penicillin Infiltration

Case	Age	Sex	Diagnosis	Associated Diseases	Units per Cc.	Volume, Cc.	Frequency of Treatment	No. of Treatments	Total Units	Other Treatment	Results
1	67	F	Carbuncle, neck	Hypertension	10,000	20	Daily	11	1,100,000	1,770,000 u. intramuscularly; hot packs	Complete resolution and healing
2	88	M	Carbuncle, back	Senility, bronchopneumonia; fecal and urinary incontinence	10,000	40	Daily	11	2,200,000	310,000 u. intramuscularly; excision of necrotic center; attempt at grafting failed	Healing with epithelization without grafts
3	2	M	Abscess, right arm	Lymphadenitis	10,000	15 10 8	Daily	3	165,000	None	Healed with spontaneous drainage
4	35	M	Cellulitis, multiple with abscess formation	Lymphadenitis	40,000	5	Daily	4	400,000	None	Healed
5	34	M	Cellulitis, arm, with abscess	Lymphadenitis	20,000	10	Daily	2	200,000	50,000 u. into abscess; streptomycin, 4 Gm. (1 Gm. daily) and penicillin, 2,190,000 u. parenterally; incision and hot packing at another hospital without improvement	Healing; induration softening
6	66	M	Cellulitis, leg	None	20,000	10	Daily	6	700,000 (200,000 1st day)	Incision and drainage by family physician	Healing
7	42	F	Carbuncle, neck	None	10,000	20	Daily	4	400,000	None	Healed
8	30	M	Carbuncle, arm	None	10,000	20	Daily	2	200,000	None	Healed
9	37	F	Furuncle, cheek	None	50,000	2	Daily	2	90,000	None	Healed
10	20	F	Furuncle, shoulder	None	20,000	5 4	Daily	2	90,000	2 mm. incision	Healed
11	30	F	Carbuncle, arm	None	20,000	10 5	Daily	3	200,000	None	Healed
12	16	M	Cellulitis, ankle	None	20,000	5 4	Daily	4	175,000	None	Healed

as were the intramuscular administration of penicillin and the application of hot packs. In all, 2,870,000 units of penicillin was given; of this 1,100,000 units was used locally and 1,770,000 units intramuscularly.

By the third day her temperature had dropped to less than 100 F. and her white blood cell count to 7,200. She was feeling much better and eating well. The carbuncle rapidly resolved without discharging the necrotic tissue but by resorption of this material. At the time of discharge, fourteen days after admission, the lesion had completely healed, leaving an 8 mm. scar. The skin at the site of the carbuncle was still cyanotic. There was considerable residual induration of the subcutaneous tissues in this area. Three weeks after her discharge she was seen in the outpatient department. The examining physician stated that the cyanosis and some induration were still present, but that there was no evidence of infection or tenderness in the area.

This was the first case in which regional infiltration was attempted. In spite of the fact that penicillin had also been used intramuscularly, the apparent beneficial effects of the local infiltration encouraged its trial in further cases without parenteral administration of penicillin.

CASE 7.—T. E., a 42 year old female hospital employee, presented herself to the emergency room with a sore on the back of her neck, which she had noted three to four days previously. This lesion had gradually grown worse.

Physical examination revealed a well developed woman with a temperature of 97.8 F., pulse rate of 84 and a respiratory rate of 20. On the back of her neck was a carbuncle with several heads. The erythematous area measured 3 cm. in diameter. Induration involved an area about 4 to 5 cm. in diameter. It was tender and painful out to the margin of induration. There was a small draining sinus in the center of the lesion. No nodes were felt.

Local infiltration with 20 cc. of solution containing 100,000 units of penicillin was made at the outer margin of erythema. The patient suffered a moderate amount of pain. Some fluid was forced from the central core. Shortly after infiltration, the pain had disappeared. The following day the lesion had regressed, and tenderness was less. The same treatment was repeated. On the fourth day after her first treatment the indurated area was only 3 cm. in diameter. The tenderness was gone except about a small peripheral head. A third infiltration was performed, and a fourth was done two days later, at which time there had been little change. A week after the initial treatment the lesion was healed with no evidence of an active infection. There was a residual area of induration with some cyanosis of the overlying skin. A month later there was a small circular scar, 3 mm. in diameter. The tissues in the back of her neck were soft and pliable.

Here was a patient who was treated without surgical intervention and hospitalization or removal from her job with excellent results by local infiltration with penicillin.

Cultures were not taken from all of the patients with drainage, but those that were taken showed Staphylococcus aureus and/or nonhemolytic Streptococcus.

The results of these cases were most gratifying and undoubtedly much more satisfactory than those which follow conventional surgical treatment. Deforming scars were avoided and in many instances the

patients could continue their occupations. Hospitalization, when it was necessary, was greatly shortened. The minimal daily dosage and number of treatments have not been established as yet.

CONCLUSION AND SUMMARY

Regional infiltration of localized infections with penicillin solution is a superior method of therapy. As much as 200,00 units can be infiltrated at any one time into the subcutaneous tissues about an infection without causing toxic reactions or sloughs. Total disability is greatly reduced with this method of therapy, and the deformities that result from surgical incision or excision are avoided. Inflammatory pain is quickly relieved after infiltration, and this relief is generally permanent after the first or second treatment. Infiltration is moderately painful, but the pain does not last more than ten to twenty minutes if the penicillin solution contains 0.5 per cent procaine hydrochloride.

Dr. P. B. Price gave encouragement and helpful criticism.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1945

A Review Prepared by an Editorial Board of the American Academy of Orthopaedic Surgeons

XIX. CONDITIONS INVOLVING THE ELBOW, THE FOREARM, THE WRIST AND THE HAND

Prepared by

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Surgical Anatomy.—Kropp[692] reported a communication between pisotriquetral and radiocarpal joints in 76 per cent of fifty-six joints examined in 28 subjects. Usually this joint is described as completely separated from the cavity of the radiocarpal joint. In only two anatomic atlases was he able to find evidence of the communication between pisotriquetral and radiocarpal joints.

Sunderland[693] made a study on the action of extensor digitorum communis, interosseous and lumbrical muscles. The purpose of this paper was to record observations on the actions of these muscles in cases of lesions of peripheral nerves in which conditions were favorable for examination of isolated and combined muscle action. The flexor action of the interossei at the metacarpophalangeal joint and the extensor action of the lumbrical muscles and the extensor digitorum at the interphalangeal joints are contentious points and are given special consideration. The lateral movements of the digits are not included in this study. After a review of the literature, the anatomy is discussed and cases for study are selected in which the third and fourth lumbrical muscles and all interossei participated. Evidently these muscles require assistance of other muscles for their proper functioning. The significant feature of a motor response is the integrated character of the muscular mechanism responsible for it. It is misleading to speak of isolated, individual and specific actions of the extensor, lumbrical and interosseous muscles. They function as a well integrated and coordinated group in every movement of the digits, combining to give that delicacy, refinement and precision of action which forms the basis of manual dexterity. Synergistic control prevents excess expenditure of energy and relieves tension.

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692. Kropp, B. N.: Note on Piso-Triquetral Joint, Anat. Rec. **92**:91-92 (May) 1945.

693. Sunderland, S.: Actions of Extensor Digitorum Communis, Interosseous and Lumbrical Muscles, Am. J. Anat. **77**:189-217 (Sept.) 1945.

Kaplan [694] reported observations on 40 hands dissected personally and 60 observed while being dissected by medical students. He noted there was a constant relation between the tendons of the flexor sublimis and the flexor profundus to the index finger with the median nerve and the palmaris longus tendon. The palmaris longus tendon is used as a key to locate other structures in the wrist. The median nerve and the flexor profundus tendon to the index finger lie directly beneath the palmaris longus tendon, the profundus being more dorsally placed. To the radial side of the median nerve and the tendon of the flexor profundus indicis is found the flexor hallucis longus tendon. To the ulnar side of the deep flexor of the index, but beneath the flexor sublimis to the middle finger, is found the flexor sublimis to the index finger and further ulnarward the flexor profundus to the third, the fourth and the fifth finger in the order named. The tendons of the flexor sublimis to the fourth and the fifth finger lie anterior to the tendons of the respective deep flexor muscles. A discussion of the anatomic variations for the various nerves and tendons is given. The palmaris longus was absent in 11 per cent of the cases according to Le Double and in 3 of the author's cases, and the median nerve may be divided into two trunks. There is frequently extensive fusion of the tendons of the flexor sublimis and the flexor profundus to the fourth and the fifth finger. Various accessory tendon slips may be found as well as variations in the usual tendon pattern.

Another review was on the significance of insertions of the extensor communis digitorum in man, also reported by Kaplan.[695] The tendon of the extensor communis digitorum was dissected in 23 fresh and embalmed human cadavers. It was found that the short insertion into the base of the proximal phalanx occurred in only 38.5 per cent of the 140 fingers examined. Anatomic investigation showed that this insertion, contrary to accepted belief, is not essential functionally. The action of the extensor apparatus and of the intrinsic muscles of the hand was studied both in the cadaver and by electrical stimulation in more than 100 living subjects. This study emphasized the importance of the connection between the extensor tendon and the capsule of the metacarpophalangeal joint in the normal extension of the phalanges. There is a detailed description of the material and methods employed and experimental findings, followed by a discussion.

Osteochondritis Dissecans.—A short general discussion of osteochondritis dissecans is presented by Millman.[696] A discussion of cases

694. Kaplan, E. B.: Surgical Anatomy of Flexor Tendons of Wrist, J. Bone & Joint Surg. **27**:368-372 (July) 1945.

695. Kaplan, E. B.: Functional Significance of Insertions of the Extensor Communis Digitorum in Man, Anat. Rec. **92**:293-303 (July) 1945.

696. Millman, W. S.: Osteochondritis Dissecans of Supratrochlear Septum, Canad. M. A. J. **53**:55-57 (July) 1945.

presented in the literature is given which indicates that the correct procedure would be surgical excision of the bodies. A report is included of a case in which surgical treatment was given.

Kienböck's disease constitutes a convenient clinical designation, but this term does not represent a definite pathologic entity according to Etcheverry.[697] In 1940, the author presented a report on clinical and roentgenologic findings in 2 cases of Kienböck's disease. The patient described in the present paper was 24 years of age and had suffered from influenza at 17 years, but had no history of injury. Seven months before admission she suffered slight pain in her left wrist. Roentgen examination suggested tuberculosis of the radiocarpal joint, and the latter was immobilized for five months. On removal of the cast, however, symptoms recurred. Examination revealed a slight swelling of the dorsal surface of the left wrist with slight palmar flexion and cubital inclination. Hyperextension was painful. Roentgen examination revealed changes in the semilunar bone. The role of rickets, trauma and syphilis is discussed. Infection constitutes a predisposing factor. Latent inflammation may cause symptoms of aseptic necrosis of bone. Other possible causes include embolic changes, improper treatment of fractures, scaphoiditis and primary occupational fracture. A possible embolus during influenza is suggested. This condition is known as an occupational disease of workers employed in compressed air operations. A detailed description of the specimen is presented. No changes in the vessels could be demonstrated. Anatomic analysis indicates an internal paramedian incision corresponding to the inferior radiocubital articulation below which one will find the semilunar bone in normal subjects.

The various theories as to the causation of Kienböck's disease are reviewed by Persson.[698] Conservative treatment and extirpation of the lunate bone have both yielded unsatisfactory results. Hulten in 1928 explained the predilection for this condition at the wrists as due to protrusion of the radius over the ulnar end, the so-called minus radiant. In 1932 Hulten reported a case in which roentgenologic healing occurred two years after shortening of the protruding radius. In 3 cases in which Persson tried shortening of the radius a satisfactory healing tendency was gradually observed in the lunate, but in 2 cases a curvature of the radius occurred in the first plaster of paris bandage so that the place of osteotomy on the radius approximated the ulna and healing took place in that position, with resulting limited pronation and

697. Etcheverry, A. J.: Los fundamentos anatómicos de la enfermedad de Kienböck, Amatus **3**:300-310 (May) 1944; Rev. españ. cir., traumatol. y ortop. **1**:331-339 (Nov.) 1944.

698. Persson, M.: Pathogenesis and Therapy of Kienböck's Disease: Fracture Theory in Light of Efficacy of Operative Shortening of Radius (Hulten) and New Operation (Lengthening of Ulna), Acta chir. Scandinav. (supp. 98) **92**:1-158, 1945.

supination of the forearm. Lengthening of the ulna is simpler from a technical standpoint and results in no tendency toward any curvature of the axis at the site of osteotomy. Fourteen cases in which the ulna was lengthened by Persson were followed for one and one-half to ten and three-fourths years. Lesions causing disablement developed in only 2 of 19 cases in which operation was done as compared with 56 of 162 controls. There were slight or no subjective symptoms in 14 patients. The mobility of the wrist is greater by this method. Pronation and supination of the forearm were limited in all 3 cases in which the radius was shortened, but in only 1 of 16 cases in which the ulna was lengthened. The muscular strength in 18 patients on whom the operation was done was 5.6 Kg. greater as measured by the dynamometer than in 109 controls. Muscular atrophy was less pronounced and the roentgenologic picture of the lunate showed better results. Arthrosis deformans had developed or had been aggravated in 10 of 19 cases in which the operation was done. This operation is not indicated in cases of far advanced Kienböck disease with marked fragmentation of the lunate, or in far advanced arthrosis deformans, or in cases in which defective healing was already present with roentgenologic sclerosis of the whole bone.

McMaster and Levin[699] reported the following case of osteochondritis dissecans of a carpal scaphoid. A machinist of 21 years suffered from pain and stiffness of the left wrist. He awoke suddenly with pain one morning three weeks previously. There was no history of injury. He was unable to continue work. Examination revealed a localized tenderness over the carpal scaphoid and somewhat limited mobility of the wrist. From the age of 9 to 19 years he had suffered intermittent attacks of rheumatic fever. Cardiac examination revealed a definite late diastolic murmur at the apex. The impression obtained was that of a compensated mitral stenosis. Roentgen examination of the wrist revealed an oval circumscribed area of the scaphoid with slightly increased density on the radial articular cortex with a surrounding thin area of rarefaction. The other joints were normal. No operation was attempted. It is suggested that possibly an embolus may have lodged in the scaphoid with consequent local necrosis. As a rule osteochondritis dissecans is caused by injury.

It is Wanke's[700] feeling that the term osteochondritis should be replaced by osteochondrosis. A complete discussion of the mechanism of production is presented. All osteochondroses, regardless of the

699. McMaster, P. E., and Levin, R. T.: Osteochondritis Dissecans of Carpal Scaphoid, U. S. Nav. M. Bull. **45**:742-744 (Oct.) 1945.

700. Wanke, R.: Bemerkungen zum Formenkreis der Epiphyseonekrosen, insbesondere zur Osteochondrosis dissecans cubiti (Konig), Chirurg **15**:614 (Oct. 15) 1943.

articular location, have a uniform pathologic anatomic basis, namely the subchondral epiphyseal necrosis, usually of circumscribed form. The peculiar and constant anatomic position of the necrosis in the different joints with only rare exceptions is evidently determined by the peculiar structure of the joint involved. The static position of a certain portion of the epiphyseal bone in the head of the joint favors development of necrosis as a result of exhaustion fracture. The course and eventual outcome of necrosis of epiphyseal bone depends, furthermore, on the mechanics of the involved joints. In joints with predominant hinge mechanism one usually encounters the dissecans type, and in ball and socket joints the deforming type. A new diagnostic sign for osteochondritis dissecans cubiti is described; i. e., circumscribed sensibility to pressure and percussion of the head of the humerus demonstrable between 14 and 18 years of age. The sign is demonstrable only with the elbow in pronounced flexion. The so-called axial roentgenogram of the elbow joint is indispensable for more accurate demonstration of the focus. The author recommends posterior arthrotomy with a small incision between the olecranon and the lateral epicondyle for exposure of the necrotic focus and for the removal of free joint bodies if the latter are still in the "mouse bed" or in the posterior joint sac.

Instability and Dislocation of Smaller Joints.—A discussion of the possibilities of a painful distal radioulnar joint after Colles' fractures is presented by Regan and Bickel.[701] In inadequately reduced Colles' fractures the distal ulnar joint will frequently slip dorsally on rotation. A review of various surgical procedures for correcting this was presented. Two cases were presented in which treatment was by forming a sling with fascia lata to prevent subluxation of the ulna. The fascia lata was threaded through a hole in the distal radius and about the ulna. General discussion of ligamentous and fascial operations to prevent subluxation of various joints was presented.

Eggers [702] presented a surgical procedure for correction of dislocation of the first carpal metacarpal joint. A surgical procedure is described in which a portion of the extensor carpi radialis longus is split off and threaded through a hole near the base of the metacarpal and sutured back on itself. Plaster fixation was carried out for a period of two weeks, followed by active motion. In a follow-up of ten months there is no evidence of redislocation.

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701. Regan, J. M., and Bickel, W. H.: Fascial Sling Operation for Instability of Lower Radio-Ulnar Joint, Proc. Staff Meet., Mayo Clin. **20**:202-208 (June 13) 1945.

702. Eggers, G. W. N.: Chronic Dislocation of Base of Metacarpal of Thumb, J. Bone & Joint Surg. **27**:500-501 (July) 1945.

Arthroplasty of the Elbow.—Boerema and de Waard [703] reported experience on work in the use of bridging defects in the elbow by use of plates of V_2A steel. It is their feeling that a bony union between the plate and the joint is not essential. By this means a useful extremity may be obtained even if pseudarthrosis persists. Such a prosthesis grafted into a formerly ankylotic elbow joint resulted after one year in a range of motion of 20 degrees without pain and a useful forearm. In 1933, Boerema reported experimentally that in open fractures a periosteal injury may lead to delayed regeneration of bone and in some cases to pseudarthrosis. It was noted that formation of bone on both ends of the pseudarthrosis was even more active than normal. It was believed possible that the regenerating bone tissue would grow around and into the prosthesis, thus rendering the prosthesis immobile and fixedly anchored in the bone fragment. V_2A steel is nontoxic, non-absorbable, strong, tough and easily molded. In a tubular prosthesis the bone was found growing into the lumen of the prosthesis. The prosthesis is inserted so far into the fragments that pressure is divided not only through the ends but through a whole column of bone. The holes in all parts of the prosthesis are 2 to 3 mm. in diameter. The simplest form is a V-shaped rod with only 3 cm. in the center free from holes. A case is reported in detail in a woman of 48 years with a fracture of the humerus. Although the pseudarthrosis has not healed she has good mobility. This same method with holes may be used to aid in fixation of Smith-Petersen nails. One case is described in which good results were obtained by this method in a woman both of whose elbows became ankylosed after arthritis as a sequel of scarlet fever.

Radioulnar Synostosis of Traumatic Origin.—In a review of the medical literature few cases of synostosis of the bones of the forearm are reported. A report of a case is presented by Lee [704] in which the synostosis occurred in the middle of the forearm. An open reduction had been performed four days after the injury and a plate applied to the radius. At the end of three months there was no clinical rotation of the forearm whatsoever, the roentgenogram revealing bony union between the radius and the ulna. At the end of that time surgical excision of the synostosis was carried out and resulted in 75 per cent of a normal rotation.

[ED. NOTE: Many cases of synostosis of the bone of the forearm have been observed as a result of several war injuries. Surgical excision has been rather satisfactory if too severe scarring is not present.]

703. Boerema, I., and de Waard, D. J.: Osteoplastische Verankerung von Metallprothesen bei Pseudarthrose und bei Arthroplastik, Acta chir. Scandinav. **86**:511-524, 1942.

704. Lee, H. G.: Radioulnar Synosteosis of Traumatic Origin, New England J. Med. **232**:498-499 (May 3) 1945.

A discussion of fracture dislocations of the elbow in children with dislocation of the internal epicondyle into the joint is presented by Schmier.[705] A dislocation of the internal epicondyle into the joint is often unrecognized with resulting serious disability. A method of closed reduction of the dislocated epicondyle is presented. The method includes supination of the forearm and extension of wrist, elbow and fingers, thus putting tension on the muscles attached to the epicondyle, which will in turn reduce it from the joint. The method is not suitable for old cases; in such cases an open reduction is necessary. There may be a stretching of the ulnar nerve at time of dislocation in which a later neurolysis may be indicated. Some cases were presented with a dislocation of the elbow and fracture of the medial epicondyle, which was dislocated into the joint.

Boutrous, Blain and Chipman [706] report 20 cases of fractures of the elbow treated by nonsplinting and early mobilization. The first 12 cases reported were apparently mild or questionable fractures without displacement which were handled by a sling and early motion. In the second group of cases the fractures were severer and with some displacement of fragments. In this group of cases closed reduction was necessary, with the exception of 2 which required open reduction. In the second group, splinting was used for a short period before the institution of active and passive motion. It was the authors' feeling that a short period of plaster fixation was indicated in many fractures of the elbow. No roentgenograms were shown of the severer fractures, so that the actual situation of fractures cannot be evaluated.

Cox, Parnell and Sobatier [707] report their experience in acute injuries of the hand in the Mediterranean Theater of Operations. Their early experience was disappointing, and after a plea for discontinuing plaster fixation and traction splints for severe wounds of the hand caused by high explosive missiles, a method of treatment consisting of débridement, preserving all visible tissue, immobilizing with pressure dressing and with the proximal joint in 80 to 90 degree flexion is outlined. It is the thought of the authors that the immobilization of the soft tissue and prevention of swelling and induration as such were more important than the position of the fracture and that the fracture, tendon and nerve repair could be handled after the acute injury had healed.

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705. Schmier, A. A.: Internal Epicondylar Epiphysis and Elbow Injuries, Surg., Gynec. & Obst. **80**:416-421 (April) 1945.

706. Boutrous, T. A.; Blain, A., III, and Chipman, W. A.: Nonsplinting Treatment of Elbow Joint Injuries: Report of Its Use in Twenty Cases, Am. J. Surg. **68**:212-218 (May) 1945.

707. Cox, F. J.; Parnell, H. S., and Sobatier, J. A.: New Type of Hand Dressing to Improve Function, M. Bull. Mediterranean Theat. Op. **2**:168-169 (Dec.) 1944.

An excellent review of modern methods of management of lacerated flexor tendons and their relation to mechanical and physiologic observation on experimental work is presented by Kinmonth.[708] He discusses the physiology of the tendon repair, period of immobilization and the choice of operation as to whether a free graft, suturing of the lacerated tendon or arthrodesis of the terminal interphalangeal joint should be done. The other choice would be amputation, which sometimes is advisable in unskilled workers. He stresses the importance of considering the patient's age, occupation, intelligence and whether or not nerves were severed and the extent of loss of skin and sepsis. He tries to maintain minimal adhesions at the site of anastomosis by the proper length of graft. Adequate period of rest before activity and physiologic incision of the skin and later gentle manipulation are advised.

Burman [709] states that great difficulty is encountered in attempts to repair a torn or adherent flexor tendon of a finger within its sheath. A sheath is required in which the tendon will move smoothly. For this purpose colloidin tubes have been implanted into the finger three to four weeks before tenoplasty with successful results. A nylon tube made of extremely fine nylon is described and was used in 2 cases to duplicate the tendon sheath. The tube was placed about the free tendon graft used for repair. Nylon was chosen because it is flexible and well tolerated and because fluid collects about it. The technic is described in detail with illustrations. Good results were reported in these 2 cases. The sheath was well tolerated and permitted smooth gliding of the transplanted tendon.

A case is reported by Gordon [710] in which there was pronounced evulsion of the soft tissue from the thumb. The author describes a method of repairing the thumb and restoring the length by the use of a tubed pedicle from the abdomen. Open reduction of the fracture involving the interphalangeal joint was necessary, the soft tissue being lost from the distal phalanx. The phalanx was put into the tube. This resulted in a full length thumb with no motion at the interphalangeal joint, the abdominal skin covering of which was anesthetic. There was ability to oppose and approximate the tip of the thumb to each of the fingers.

Immobilizing Splinting of the Hand.—An outstanding report is given by Bunnell [711] on the improper and inadequate early mobilization and care of war injuries to the hand. A survey of the general hospital in

708. Kinmonth, J. B.: Cut Tendons, with Special Reference to Flexor Tendon Cut Within Its Digital Sheath, St. Thomas's Hosp. Gaz. **42**:154-158 (Dec.) 1944.

709. Burman, M.: Use of Nylon Sheath in Secondary Repair of Torn Finger Flexor Tendons, Bull. Hosp. Joint Dis. **5**:122-133 (Oct.) 1944.

710. Gordon, S.: Autograft of Amputated Thumb, Lancet **2**:823 (Dec. 23) 1944.

711. Bunnell, S.: Suggestions to Improve Early Treatment of Hand Injuries, Bull. U. S. Army M. Dept., May 1945, no. 88, pp. 78-82.

the Zone of the Interior indicated that considerable crippling of hands could have been prevented with proper early treatment in the theater of operation. The most common disability was stiffening of joints from position of the hands and excessive induration and malunion of fractures. The author recommends that splinting should include only the injured portion of the hand. He also advises early action of the muscles and tendons to improve circulation. Granulating areas should be covered with a thin split skin graft. This can later be replaced by a pedicle graft. Malunion can be prevented by early traction in the direction which gives the proper alinement. Many illustrations to show proper method of traction are included.

Nachlas[712] presents a comprehensive discussion of the mechanism of developing a fixed extension contractor of the metacarpophalangeal joint of the hand following injury. He describes the difficulty in restoring function to the metacarpophalangeal joint and presents a type of splint for correction of this deformity. Excellent illustrations of the splint are presented. The splint itself consists of the type frequently used in fractures of the wrist, with addition of the palmar bar which extends anterior to the palm for the purpose of bringing traction straps over to produce constant traction on the metacarpophalangeal joint.

A complete and comprehensive review and recommendations for immobilization of the hand are presented by Pratt.[713] The author emphasizes the importance of observing the best possible functional position of the wrist and digits in immobilization of the hand. Only the minimum amount of rigid fixation compatible with the injury involved is indicated. The metacarpophalangeal or interphalangeal joints should never be immobilized in extension. A satisfactory temporary board and wire splints are shown with wrist cocked up, fingers flexed and thumb free. For effective immobilization, splints or casts must be form fitting and must include at least two thirds of the circumference of the limb. The joints immediately above and below the fracture should be included. If stabilization is required after reduction, skeletal fixation or fixation with a nonpadded or lightly padded cast is recommended. In recent injuries and for more inexperienced surgeons, padding is safer. The cast must be bivalved. The optimum positions for the various joints in fixation are described, including elbow, wrist, palmar arch and thumb. The latter should never be immobilized in the flat or side position, and the fingers never beyond the metacarpophalangeal joints, unless this is definitely indicated and then briefly in semiflexed position. Special care in immobilization for fractures of the metacarpals and phalanges is urged. The metacarpophalangeal joints

712. Nachlas, I. W.: Splint for Correction of Extension Contractures of Metacarpophalangeal Joints, J. Bone & Joint Surg. **27**:507-512 (July) 1945.

713. Pratt, D. R.: Suggestions on Immobilization of Hand, Arch. Phys. Med. **26**:649-653 (Oct.) 1945.

should always be kept mobile unless it is absolutely unavoidable and should then be splinted in position of flexion. The various uses of plaster of paris in splinting the hand are discussed, as well as of metal splints for the wrist, and instructions are given for the splinting of extremities with injured nerves. Elevation of the hand and making the cast bivalved lessen the danger of dependent edema. Prolonged or too extensive immobilization is described as leading to atrophy and stiffening. Function of the wrist can be maintained by finger exercises.

Bacteria of Wounds of Hands.—Williams and Miles [714] made a bacterial survey of 1,200 clean and septic wounds to determine the relative importance of the various bacterial species as causes of sepsis in common small wounds of the hand resulting from industrial and domestic accidents. The results are classified according to the nature of the lesion. Staphylococcus aureus and Streptococcus pyogenes were found to be the predominating causes of infection. Staph. aureus was isolated from 21 per cent of 432 fresh wounds, 37 per cent of 278 apparently healthy, 82 per cent of 142 clinically septic cuts and 88 per cent of 345 other septic lesions. The percentages of wounds yielding Str. pyogenes were 1, 3, 18 and 26 respectively. Only 8 per cent (39) of the 487 septic lacerations and other septic lesions failed to yield Staph. aureus or Str. pyogenes, though 12 yielded Staph. aureus in later samples. Bacteria of presumed fecal origin were rarely found in wounds of the hands. The majority of infections of the hands developing as closed lesions, e. g., paronychia and large septic lacerations, commonly yield Str. pyogenes as well. This suggests that Str. pyogenes infections result from long exposure to relatively low risk and that many of them are added after infection of the wound.

Volkmann's Ischemic Contracture.—O'Connell [715] describes a case in which the patient was admitted for arthrodesis of the wrist. However, owing to the presence of severe contracture, it was felt that a sudden correction would cause circulatory obstruction. To prevent this, a preliminary course of gradual splintage was applied to obtain maximum correction prior to operation. A full length plaster of paris cast was applied from below the elbow to beyond the finger tips with the wrist palmar flexed and the fingers straight. The back of the plaster was cut away to expose the distal interphalangeal joints. The patient was instructed to extend the fingers voluntarily at these joints. A careful watch should be kept for pain or circulatory changes in the finger tips. A stockinet glove and a strip of plaster wool down the flexor aspect of the forearm and wrist were used as padding. This plaster was removed two weeks later, when the patient could extend the wrist a further

714. Williams, R. E. O., and Miles, A. A.: Bacterial Flora of Wounds and Septic Lesions of the Hand, J. Path. & Bact. **57**:27-36 (Jan.) 1945.

715. O'Connell, J. G.: Conservative Treatment of Volkmann's Ischemic Contracture, Proc. Roy. Soc. Med. **38**:688-689 (Oct.) 1945.

10 degrees with fingers extended. New plaster was applied in the position of maximum correction and left on for three weeks. Two further changes of plaster were needed before the wrist came into dorsiflexion with fingers extended. It was decided to persevere with splintage. Hyperextension deformity at the metacarpophalangeal joints still persisted and would probably grow worse if the full length plaster was persevered with. Therefore, an anterior plaster slab to hold the wrist in 15 degrees of dorsiflexion was applied with individual splints for each finger (Jones) made from 2 inch (5.1 cm.) cellulose plaster bandages. The patient was encouraged to flex and extend actively at the metacarpophalangeal joints and to report any tendency to flexion. These splints and "cock-up" were renewed twice. After two months the finger splints were discarded, the cock-up splint being retained. Active and passive flexion and extension of fingers were present. The cock-up splint was removed after three months. There was no tendency to relapse.

Thenar Palsy.—A historical discussion of papers dealing with atrophy of the muscles of the thenar eminence is presented by Zachary.[716] An excellent review of the literature is given and reports of cases are summarized. Two cases are reported in which a paralysis of the thenar muscles supplied by the median nerve are presented. It is the author's feeling that the paralysis is due to compression of the median nerve as it passes through the carpal tunnel. In both cases presented there was a history of old injuries to the wrist, and in 1 of them there was a rather sharp bony protruberance over which the nerve passed. In the first case the paralysis was bilateral, and there was little benefit from surgically freeing the nerve. The follow-up was for only three months. There was complete recovery in the other patient as a result of freeing the nerve in the carpal tunnel. Various theories of causation are discussed, and it is his feeling that a portion of a nerve may be involved, thus accounting for motor weakness and normal sensation.

De Quervain's Disease.—Aitken[717] reports a series of 15 cases of de Quervain's disease. It is his belief that the condition is due to the divergence of the tendon of the abductor pollicis longus and the extensor pollicis brevis as it passed the distal end of the bony groove in the distal radial styloid. He considers that the tension exerted repeatedly at a sharp angle produced the thickening of the fibrotic sheath. He also feels that there is a definite relation between this condition and so-called trigger finger or thumb. The condition is more frequently found in women than in men, and it is felt that there will be

716. Zachary, R. B.: Thenar Palsy Due to Compression of Median Nerve in the Carpal Tunnel, Surg., Gynec. & Obst. **81**:213-217 (Aug.) 1945.

717. Aitken, A. P.: Stenosing Tendovaginitis at Radial Styloid Process (de Quervain's Disease), New England J. Med. **232**:105-107 (Jan. 25) 1945.

a steady increase as there are more women now employed in industry. A description of Finkelstein's test is given, which is said to be pathognomonic of the disease. Treatment is surgical excision of the stenosed sheath with early motion and resumption of work in two weeks.

Patterson and Jones [718] present a study on stenosing the tendovaginitis at the radial styloid. They brough out that the condition was described in the thirteenth edition of Gray's "Anatomy," published in 1893, two years prior to the publication by de Quervain. It is their feeling that the thickening of the tendon of the abductor pollicis is due to the mechanical irritation from the tendon passing through the synovial sheath. The condition is also known as "washerwoman's sprain." The etiologic factor is undoubtedly trauma. There is great preponderation of this disease in women. The onset of the symptoms is gradual and progressive. They may develop to such an extent that the patient will drop small articles. There is a definite weakness of the thumb due to pain. The authors believe that there are a few cases in which there is benefit from conservative treatment but that operative intervention is the treatment of choice. By surgical intervention the period of disability is tremendously shortened.

Roentgenographic Examination of Carpus.—Roderick [719] states that there is no generally accepted series of positions to supplement the standard posteroanterior and mediolateral projections of the carpus. He examined fifty roentgen projections of a normal wrist to determine the minimum number of positions required for demonstration of all the carpal bones and joints. Various roentgenologists were consulted as to their opinions. It was concluded that at least five projections were needed for complete examination of the carpus to show each carpal bone in one or more perspectives and the relationship of each carpal bone to surrounding structures and to outline the articular surfaces and interspaces. The supplementary positions required when conditions will permit include the following: (1) posteroanterior view, (2) oblique anteroposterior view, (3) oblique posteroanterior view, (4) lateral mediolateral view and (5) axial view.

An excellent review of bony changes suggested in roentgenograms of the hand in various metabolic, endocrine and congenital diseases has been presented by Holt and Hodges.[720] Illustrative roentgenograms of various conditions are presented with an excellent discussion of each disease. There are certain changes found in thromboangiitis obliterans,

718. Patterson, D. C., and Jones, E. K.: de Quervain's Disease: Stenosing Tendovaginitis at Radial Styloid, Am. J. Surg. **67**:296-301 (Feb.) 1945.

719. Roderick, J. F.: Roentgenographic Examination of Carpus, Am. J. Roentgenol. **53**:611-614 (June) 1945.

720. Holt, J. F., and Hodges, F. J.: Significant Skeletal Irregularities of Hands, Radiology **44**:23-31 (Jan.) 1945.

cretinism, achondroplasia, etc., which are diagnostic of the diseases. They feel that a roentgenogram of the hand should be a routine examination and that it would be extremely helpful in differential diagnosis.

A short review of the literature on congenital fusion of carpal and tarsal bone is presented by Henry.[721] It is the author's conclusion that fusion of the carpal bones is hereditary and that the trait is transmitted according to the mendelian law as a dominant factor which is not sex linked. A report of a case is included.

Wendt, O'Hare and Aronstein[722] present an interesting case of sclerodactylia with atrophy of the terminal phalanges. The patient was a Mexican woman of 43 years who had suffered from tenderness of the fingers for the past six or seven years. No previous roentgen examination had been made, and no diagnosis had been offered. Her fingers and hands were indurated, swollen and red. Pressure at the base of the finger nails caused exquisite pain. Roentgen examination revealed advanced absorption in all the terminal phalanges in both hands except the fifth finger of the left hand. Although a small fragment of bone remained in the distal ends of four of the fingers, the absorptive process had generally progressed so that only a small portion of each phalanx was present distal to the joint. The second and third phalanges of each digit were somewhat narrowed but showed definite evidence of atrophy. The diagnosis was sclerodactylia associated with destruction of the terminal phalanges.

XX. CONDITIONS INVOLVING THE SPINE AND THORAX, EXCLUSIVE OF THOSE IN THE LOWER PART OF THE BACK

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Roentgenography.—Rush[723] describes and illustrates a device for spinal fixation and stabilization for roentgenograms of the spine in the standing position. The author feels that this device is helpful, especially when many patients are to be examined and with changing technical personnel.

In pointing out the advantages of this device, he states that fixation and stabilization are assured, that a multiplicity of positions may be obtained by simple maneuvers, that accurate posteroanterior, anteroposterior, lateral and angle positions are assured and can be reproduced at will, and that it provides an accurate means of measuring length of the legs.

721. Henry, M. G.: Anomalous Fusion of Scaphoid and Greater Multangular Bone, Arch. Surg. **50**:240-241 (May) 1945.

722. Wendt, D. D.; O'Hare, J., and Aronstein, E.: Sclerodactylia with Atrophy of Terminal Phalanges, Radiog. & Clin. Photog. (no. 1) **21**:20, 1945.

723. Rush, W. A.: A Roentgenographic Spinal Fixation and Stabilization Device, Am. J. Roentgenol. **54**:187-189 (Aug.) 1945.

[ED. NOTE: This device would probably be of value in studying certain spinal lesions when it is desirable to take roentgenograms at intervals with exactly the same position and angle.]

Slauson [724] presents a method for roentgenography of the lateral lumbar part of the spine. He varied the tube-film distance in order to obtain satisfactory roentgenograms demonstrating clearly each intervertebral space, utilizing the divergence of the roentgen beam and distance.

Wilsey, Holly and Cornwell [725] review the problems of lateral roentgenography in the lumbar lumbosacral region. The authors point out that lateral roentgenography of the lumbar and the lumbosacral region is usually conducted as two separate examinations, since that procedure is most easily adapted to routine exposure technic. There are occasions, however, when for anatomic and economic reasons it is desirable to visualize the lumbar and the lumbosacral region together by means of a single lateral projection on one 14 by 17 inch (35.6 by 43.2 cm.) film.

To accomplish this, it requires special precaution in order to secure roentgenograms of good technical quality. The authors discuss the technical difficulties involved and the methods of overcoming them. The discussion covers the use of high kilovoltage technic as a means of visualizing an extensive range of tissue thickness, control of scattered radiation, and roentgen ray filtration for balancing the lumbar and the lumbosacral images. They give illustrations to show the contours of lead mass that have been found practical for alinement with the patient's back to shield the Potter-Buckey diaphragm from direct radiation. Roentgenographic reproductions illustrate improved visualization using lead mass anterior and posterior to the vertebral column compared with those without the lead mass which are fogged by scattered radiation.

Wagoner, Hunt and Pendergrass [726] continue their work (some of which has been previously reported) on the various roentgen shadows of human vertebral bodies in an excellent article on a study of the relative importance of cortex and spongiosa in the production of the roentgenogram of the normal vertebral body. They discuss the relative "shadow values" of the cortex and of the spongiosa of the vertebral bodies, the transverse markings seen in the lateral roentgenogram of 10 to 20 per cent of human vertebral bodies and the minimum size of a lesion in the spongiosa detectable roentgenographically.

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724. Slauson, D. B.: A New Principle in Roentgenography of the Lateral Lumbar Spine, Radiology **44**:280-282 (March) 1945.

725. Wilsey, R. B.; Holly, E. W., and Cornwell, W. S.: Special Problems in Lateral Radiography of Lumbar-Lumbosacral Region, Radiog. & Clin. Photog. (no. 1) **21**:2-8, 1945.

726. Wagoner, G. W.; Hunt, A. D., and Pendergrass, E. P.: A Study of the Relative Importance of the Cortex and Spongiosa in the Production of the Roentgenogram of the Normal Vertebral Body, Am. J. Roentgenol. **53**:40-48 (Jan.) 1945.

They describe a series of experiments for investigating these points. They conclude that the spongiosa is the more important component in the production of the roentgenographic shadow pattern of the normal vertebral body, that the "transverse line" is due to the presence of a well developed sinusoidal reservoir located within the spongiosa and that the cortex plays no part in the production of this marking. They also conclude that large defects of the lateral cortex are not recorded in roentgenograms and that much smaller defects of the spongiosa are clearly seen.

The author points out that these studies explain why in many instances it is difficult to demonstrate metastatic lesions whether of malignant or infectious origin even in the presence of strong clinical evidence that a lesion may be present, and in practice one not infrequently has to deal with confusing shadows of other structures.

[ED. NOTE: This paper has numerous, excellent roentgenograms and photographs and is well worth complete study by those interested in roentgenography of the spine.]

Diseases of the Spine.—Johnson and James [727] report an unusual case of suppurative typhoid of the spine in which a paravertebral abscess formed which perforated into the lung. The length of the latent period, the confusing symptoms and the efficaciousness of treatment were of special interest.

The patient, aged 34, gave a history of typhoid twenty-two years before and complained of intermittent lumbago and sciatica of ten years' duration. Serum agglutinations for typhoid were positive, and aspiration of the abscess showed pure typhoid cultures. Treatment consisted of administration of sulfathiazole, incision and drainage of the abscess, bed rest and use of a back brace. He was followed for two years with progressive improvement and a gain of 70 pounds (31.8 Kg.), and his sedimentation rate returned to normal.

DeGirardier [728] reports a case of painful spine with roentgen evidence of rarefaction. The patient was relieved by adequate vitamin C and bed rest. The author feels that this case confirms the work of Mourquind, who stressed the importance of vitamin C in calcium metabolism and who also showed cases of decalcification following avitaminosis C. [ED. NOTE: One wonders whether the patient's relief was due to bed rest or vitamin C.]

Franck [729] discusses the surgical treatment of interspinal osteoarthrosis ("kissing spine"). He reviews the various causative factors

727. Johnson, E. K., and James, A.: Suppurative Typhoid Spine Perforating into the Bronchus: Case Report, Am. J. Surg. **68**:103-106 (April) 1945.

728. deGirardier, J.: Painful Vertebral Osteopathy with Epiphysial Rarefactions Due to Chronic C Avitaminosis, Lyon chir. **37**:146-150, 1941-1942.

729. Franck, S.: Surgical Treatment of Interspinal Osteoarthrosis ("Kissing Spine"), Acta orthop. Scandinav. **14**:127-152, 1943.

discussed by Bastrup in 1932, including increased lordosis, an increase in the mass in the spinous processes as seen in osteitis deformans, atrophy of the vertebral bodies and the intervertebral disk, spondylosis deformans and congenital high spinous processes and low vertebral bodies or both anomalies together.

He points out that, while the lesion occurs more frequently in elderly patients, from his experience it may be encountered in the younger age group. He reports the symptoms as occurring in attacks or being of a more chronic course with pain on bending forward and backward or twisting the lumbar column. In the acute form he suggests only rest and heat. He notes that the chronic forms have been treated with immobilization and with roentgen rays. The operative treatments that have been tried consisted of spinal fusion or partial or total resection of the spinous processes involved.

The author reports 54 patients with "kissing spines"; of these, 12 were treated operatively with partial resection of the spinous processes affected. Of the 10 operative patients, 4 were relieved, 4 showed improvement and 2 remained unchanged.

The operation was performed only on patients in whom injection of procaine had relieved the pain.

[ED. NOTE: Interspinal osteoarthrosis (or "kissing spine") is a definite clinical entity, and in selective cases this operative procedure is well worth considering.]

Oppenheimer [730] states that anatomic lesions of the spine have a high incidence but produce clinical manifestations in only a minority of cases. He reports a series of 1,824 vertebral lesions of all kinds in which the correlations between clinical and roentgen findings have been analyzed during the past nine years; there were clinical signs and symptoms referable to the vertebral lesion in only 28 per cent of the patients. He discusses the diseases of the vertebral column, separating them into four groups: (1) diseases of vertebral bone (spondylosteitis), (2) diseases of vertebral symphyses, (3) diseases of vertebral synovial joints (spondylarthritis) and (4) diseases of vertebral ligaments.

He divides the first group (diseases of vertebral bone) into the following groups according to dominant morphologic characters: necrosing, predominantly rarefying, predominantly condensing and/or hypertrophic, lesions of growing bone and tumors.

He divides the second group (diseases of vertebral symphyses) into two subgroups, diseases originating in vertebral bone and diseases originating in vertebral disk, and he subdivides the diseases of vertebral synovial joints into acute arthritis, rheumatoid (atrophic) arthritis, osteoarthritis (hypertrophic arthritis, degenerative articular disease) and secondary involvement.

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730. Oppenheimer, A.: Diseases of Vertebral Column: Roentgenologic Analysis, Am. J. Roentgenol. **53**:348-369 (April) 1945.

He concludes that in general the morphologic appearances and clinical manifestations of a given vertebral disease correspond to those of the same disease involving other bones and joints.

Barceló and Vilaseca-Sabater [731] present a clinical and roentgenologic study of spondylitis due to brucellosis. They report 40 cases in which the age group was 30 to 50 most commonly. Men were effected six times more frequently than women. In 75 per cent of the cases the condition occurred in the lumbar region, in about 12.5 per cent in the cervical region and in 12.5 per cent in the dorsal area. In 4.1 per cent there were multiple foci. The vertebral involvement more commonly occurs after two or three attacks of fever; it may occur, however, at any time in the disease. It rarely occurs before the first month but frequently within the first and second months of the disease, though occasionally much later. The vertebral localization was rarely the first symptom, and the initial symptoms varied considerably. Pain may increase rapidly. The muscles and involved vertebrae may be tender, lordosis is usually decreased and there is splinting of the spine. The authors point out that it was formerly thought that no abscesses occurred, but in their series about 12.5 per cent had formation of abscess with relatively rapid formation which tended to be subacute and regressed. These abscesses did not usually cause a sinus but occasionaly drained spontaneously and absorbed easily after puncture. The pus was usually thick and yellowish green. The culture was rarely positive.

Spastic paraplegia was present in 1 case. The protein in the spinal fluid may be increased, and patients occasionally have meningeal reactions. The roentgen picture is not typical; it may show osteoporosis, osteolysis and osteosclerosis, and it may be similar to tuberculosis or streptococcic involvement.

In the cervical area there is a predilection for the anterior superior angle and the epiphyseal area. In 88 per cent of the 40 cases there were epiphyseal lesions. A narrowed disk with loss of the upper anterior angle is suggestive of this disease. In 65 per cent there were destructive lesions. The posterior elements were rarely attacked and gibbous formation was rare. In 96 per cent of the cases there were thinned disks. In only 1 case in the 40 was there no apparent disk lesion in a disk. The bodies involved tended to fuse. In the cases of acute disease, osteoporosis without any other bone changes may be noted. In 70 per cent of the cases there were local or diffuse osteophytes. Roentgenologically the authors divided the group into osteolytic, without formation of bone and similar to Pott's disease (tuberculosis of vertebrae), 23 per cent; mixed forms of relatively equal destruction and proliferation, 38 per cent, and (3) hard or osteophytic reaction with little osteolysis.

731. Barceló, P., and Vilaseca-Sabater, J. M.: Undulant Fever Spondylitis: Clinical and Roentgen Study, Med. clín., Barcelona **3**:184-198 (Sept.) 1944.

This group was hard to distinguish from osteoarthritis. The progress is more rapid than in Pott's disease and usually more acute. The localization is usually in the spongy bone, and proliferative changes are early in this condition while late in Pott's disease. The differential diagnosis, especially from osteomyelitis is difficult. It may be almost identical with osteomyelitis due to typhoid and differentiated only by serologic tests. The prognosis is good if treatment is early. The pain disappears rapidly and the abscess absorbs. Sometimes recovery is so complete that it is difficult to find residual effects by roentgen examination.

For treatment bed rest may be sufficient if pain is not severe, but the authors recommend early immobilization to relieve pain and point out that the pain is usually not relieved by analgesic drugs.

Roentgen treatment gave inconstant results. They recommend antibrucellosis serum, and they use vaccine if the fever is slight. They now use a specific intravenous vaccination and when in doubt use this as a therapeutic test. They feel that a strong febrile reaction after the intravenous administration of vaccine is a specific test for brucellosis. The first dose is given slowly in the morning with the patient fasting. Usually a chill occurs five to six hours later and lasts about thirty minutes, followed by a sensation of heat for three hours and elevation of temperature to about 104 F.

[ED. NOTE: This is an interesting paper on spondylitis due to brucellosis. Some of the roentgenographic reproductions (especially those with abscess formation) might easily be considered tuberculosis.]

Anomalies and Fractures of the Ribs.—Hagen [732] reports an interesting case of multiple fractures of the ribs in which treatment was with a Drinker respirator. He briefly reviews the physiologic aspects of the problem of the so-called "stove-in" chest and summarizes the various methods which have been used and suggested for the treatment of the patient with a severely crushed chest. He reports a 46 year old man with fractures of the second to the eleventh rib on the right side and fractures of the second to the twelfth rib on the left with overriding of the fragments of the second, the fourth and the fifth rib.

The respirator was adjusted to provide a negative pressure of 20 mm. of mercury intermittently at a rate of 36 cycles per minute. The valves were carefully adjusted to avoid positive pressure, inasmuch as it was felt that the patient needed only expansion of the chest by artificial means. Within an hour after being placed in the respirator, the patient showed improvement. By the next day he was able to do without an oxygen tent and to have the rate of the respirator reduced to 28 per minute. Three days later he was comfortable with the rate of the respirator at 21 per minute. The patient was removed from the respirator

732. Hagen, K.: Multiple Rib Fractures Treated with Drinker Respirator: Case Report, J. Bone & Joint Surg. **27**:330-334 (April) 1945.

ten days after the injury and made an excellent recovery with good healing in all the fractures.

The author points out that the patient did not experience shock, unlike most persons simularly injured, but did experience hypertension, which may have been due to the profound retardation of circulation produced by the loss of normal fluctuating negative intrathoracic pressure. The hypertension was quickly relieved when the cardiorespiratory function was restored to normal by the respirator.

The author concludes that wherever a Drinker respirator is available it is a much simpler treatment to apply than other procedures used to accomplish stabilization of the thoracic wall. It avoids the obvious risk of surgical treatment and the danger of infection associated with traction hooks in the sternum or the ribs. It also exerts a gentle nonmechanical expanding effect on the "stove-in" chest.

[ED. NOTE: While this is a report of only a single case, the dramatic improvement produced by the use of a Drinker respirator suggests that it be tried more frequently in these problems.]

Bond [733] discusses spontaneous fractures of the ribs in healthy persons and reports 3 cases. He feels that while many cases of fractured ribs from coughing in patients with tuberculosis are reported, these fractures are attributed to the decalcification of the bones and the general debility of the patient rather than to contracture of muscles. In his opinion, it is a fatigue fracture similar to the march fracture. He feels that the mechanism is similar and the movements of the ribs are comparable to the movements of and stress on the metatarsal bone.

Proctor, Campbell and Abramson [734] state that no mention can be found in the literature of fatigue fracture of the first rib. They quote Ingersoll's statement that fatigue fracture is a desirable term that denotes those fractures occurring in normal bone from repeated microtraumas and subfractural mechanical injury. The process is a gradual one, involving continual rhythmic stress on the soft tissues supporting the bony structure. When the muscles, ligaments and tendons lose their tone, the supporting function of these tissues is lost, allowing most of the stress to fall on the bone. When the bony structure itself is fatigued, fracture occurs where the stress is greater. They believe that fracture of the first rib can occur under circumstances which conform with these principles. The authors report 3 cases in which fractures of the first rib were sustained after the carrying of heavy barrack bags.

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733. Bond, T. B.: Spontaneous Fractures of the Ribs in Healthy Individuals, Texas State J. Med. **40**:642-643 (April) 1945.

734. Proctor, S. E.; Campbell, T. A., and Abramson, A. S.: March Fracture of First Rib (Barracks Bags Fracture), Bull. U. S. Army M. Dept., June 1945, no. 89, pp. 101-105.

Bowie and Jacobson [735] discuss anomalous development of the first rib simulating isolated fracture. They present reproductions of roentgenograms of 9 out of a series of 17 personally observed cases of changes in the first rib simulating fracture, and they amplify the hypothesis that these changes, callus-like formation and pseudarthrosis, are due to anomalous development. They emphasize the frequency of the occurrence of these changes and the probability that these apparent congenital changes may be mistakenly diagnosed as isolated fractures of the first rib, particularly of the spontaneous variety.

Gershon-Cohen and Delbridge [736] also write on pseudarthrosis, synchondrosis and other anomalies of the first rib. They briefly review the usual anomalies of the first rib and demonstrate congenital synchondrosis because of its similarity to pseudarthrosis following ununited fracture. They feel that pull of the muscles seems to be a just cause of fractures of the first rib as in the lower ribs and that such fractures may occur without immediate recognition. Later, however, they may be observed incidentally in roentgenograms of the lungs. Pseudarthroses may be found rarely in both first ribs. They report 1 such case and review 3 other previously reported cases. They conclude that most anomalies of the first rib are not clinically significant but the differential diagnosis between congenital synchondrosis, fracture pseudarthrosis and pathologic fracture may be important, and yet not easily made if there is an unsatisfactory history of injury or if metastatic malignant disease is suspected.

[ED. NOTE: These three papers on anomalies and fractures of the first rib suggest that the differential diagnosis may be difficult even with adequate roentgenograms, and it is probably impossible in the review of the literature accurately to differentiate between fracture and anomaly in any of the reports of cases.]

Scoliosis.—Schwartzmann and Miles [737] report their experimental results in the production of scoliosis in rats and mice. They review briefly the previous attempts of various workers to produce scoliosis experimentally in animals. In the experiments undertaken in this study the objective was: (1) to determine the effect on the alinement of the vertebral column of muscular imbalance produced by unilateral excision of groups of symmetric muscles which influence the movements and position of the vertebral column and (2) to determine the effect on the alinement of the vertebral column of muscular imbalance brought about

735. Bowie, E. R., and Jacobson, H. G.: Anomalous Development of First Rib Simulating Isolated Fracture, Am. J. Roentgenol. **53**:161-165 (Feb.) 1945.

736. Gershon-Cohen, J., and Delbridge, R. E.: Pseudarthrosis, Synchondrosis and Other Anomalies of the First Ribs, Am. J. Roentgenol. **53**:49-54 (Jan.) 1945.

737. Schwartzmann, J. R., and Miles, M.: Experimental Production of Scoliosis in Rats and Mice, J. Bone & Joint Surg. **27**:59-69 (Jan.) 1945.

by the operative release of the muscles from their attachments to the vertebrae and the prevention of their reattachments by the interposition of inert material between the muscle mass and the vertebra to which it was attached.

The authors studied the effects of unilateral removal of superficial and deep back muscles in rats. They also studied bilateral removal of superficial and deep back muscles in rats and removal of superficial and deep muscles on one side, and release of muscle attachment to spinous processes, laminas and transverse processes on the opposite side, with the interposition of an inert material to prevent reattachment.

They also studied bliateral but asymmetric excision of superficial and deep muscles. Their experiments include a series of 43 laboratory animals, and they have demonstrated that scoliosis can be produced in quadrupedal animals when muscular imbalance is obtained in those groups of muscles affecting the alinement of the vertebral column. It is also apparent that a definite time element is necessary for the scoliosis to be produced.

The authors conclude: 1. Scoliosis can be produced experimentally in laboratory rats and mice by the selective release of mechanical action of different groups of muscles on the vertebral column. 2. A satisfactory degree of control can be maintained to allow the prediction of the type of curve to be produced. 3. Selective muscular imbalance can be produced without excision of muscles by the use of inert material to prevent reattachment of muscles. This imbalance will produce lateral curvature. 4. Excision and release of muscles which did not produce imbalance resulted in no scoliosis in the animals studied.

In the animals studied, the use of "insultoic" membrane was found to be the most satisfactory, since microscopic sections through the areas of implantation of inert material showed that no local reaction of the tissue to the introduction of this substance was encountered, whereas considerable fibrosis and scarring were present around the insertions of cellophane and rubber dam. [ED. NOTE: The effect of this fibrosis in the production of the ultimate curves must also be considered.] They state that in this experiment there have been demonstrated, in vivo, some of the mechanical imbalances presented by Carey in an inanimate model. Thus scoliosis has been produced by selective muscular imbalance, which simulates the mechanical condition of paralytic scoliosis. [ED. NOTE: It should be remembered that, as the authors point out, they produced scoliosis in quadrupedal animals and that this experiment does not include the additional problem of human paralytic scoliosis, in which the effect of the supraincumbent weight and the upright position is an added factor.] In an effort to produce results earlier, the mice in experiment 2 were worked on a treadmill, since it was felt that in a system of

muscular imbalance regular exercises would increase the power of stronger or unopposed muscles and thereby would cause the scoliosis to appear sooner. They feel that this contention is supported by the results, since curvature appeared as early as one month after operation in these mice. Definite evaluation of the influence of exercise on the time required for the production of curvature in such an experiment, however, calls for a series comparable except for exercise in the same type of animal.

[ED. NOTE: This is an interesting and valuable experimental work, but one must remember that there is considerable difference between these experimental results and what one may find clinically in paralytic scoliosis in the human being. In these experiments the effect was the total removal of the forces of certain selected muscles, whereas in poliomyelitis involving the trunk or spinal muscles there may be considerable variation in the degree of involvement of muscles, and it is difficult to determine how much involvement there is in one group or which muscles are actually involved. Furthermore, these results are based on the excision of large areas of the musculature of the back, whereas in the human being there may be many thousands of possible permutations and combinations of muscular imbalance. It is difficult or impossible to predict what the forces are when there are so many possible permutations and combinations in human scoliosis due to poliomyelitis.]

Osteochondritis of the Ribs.—Lindblom [738] briefly reports on the use of roentgenography as an aid in the diagnosis of osteochondritis in the anterior ends of the ribs. He reports 12 patients operated on for established osteochondritis in 11 of whom roentgenographic changes were observed. He also reports 26 patients suspected of having osteochondritis but without operation, in 8 of whom roentgenographic changes were present and in 18 absent. The study also includes 16 normal anatomic specimens and a study of 4 patients operated on without roentgenographic examination and 4 patients with costo-osteitis operated on during the same period.

He states that in all of the cases of osteochondritis the roentgenograms showed a local swelling of the soft tissues on the inner side of the cartilage or at the junction between the cartilage and the bone. The suspected area was studied on tangential films. The swelling varied in thickness in different cases from 2 mm. to 2.5 cm. In most instances the swelling was situated at the level of the second rib. In the other cases it was noted in the region between the third and the sixth rib. Besides the swelling, signs of calcium deposit were present in 2 cases. It was difficult to distinguish these from the normal calcifications of cartilage.

738. Lindblom, K.: Subcostal Swelling of Soft Tissues in Osteochondritis, Acta radiol. **25**:610-613, 1944.

At operation an abscess of granulation tissue was found around the cartilage or at the junction of the rib and the cartilage.

He concludes that local swelling of the subcostal soft tissues at the cartilage or the cartilage and bone line is strong evidence of osteochondritis, while if these parts have a normal appearance the presence of this disease is unlikely, provided that there are no fistulas through which an abscess might have drained. The author describes the results of the study of the anterior ends of the ribs seen on tangential films and demonstrates that osteochondritis is usually accompanied by a noticeable swelling of the subcostal soft tissues. [ED. NOTE: Some of these cases were of tuberculous osteochondritis.]

Intervertebral Disk.—Knutsson [739] reports 140 cases and discusses the instability associated with degeneration of the disk in the lumbar part of the spine. He points out that anatomic specimens of the lumbar part of the spine have shown that degeneration of the disk (osteochondrosis) causes abnormal movement between the vertebrae, and it has been assumed that the clinical symptoms of this degeneration are due to this instability. In addition to the usual roentgenograms of the lumbosacral area taken with the patient lying down, the author includes profile roentgenograms taken with the patient standing and bending as far forward and backward as possible in order to make a functional test of the stability of the disk junction. By this means he was often able to demonstrate abnormal movements between the vertebrae due to loss of stability. In 71 cases the results were negative, signifying that the vertebrae and the intervertebral spaces were free of changes and that there was no instability. Of the 69 cases with degeneration of disks, in 52 only one disk was involved, in 16 two disks were affected, and in 1 three disks were affected.

Weens [740] discusses calcification of the intervertebral disk in childhood. The author reports 1 case of calcification of the disk in childhood and reviews 5 cases from the literature. All these cases were characterized by an acute episode of pain in the region of the involved segment of the spine, limited motion and spinal deformity. Rapid change in the size of the calcification or complete absorption was noted in 5 of the 6 cases described. Calcification of the nucleus pulposus in adult life is as a rule a stationary process of little clinical significance, but rather striking clinical symptoms were encountered in the cases described in childhood. In all cases reported complete recovery occurred.

The author feels that recognition of this syndrome is important in the differential diagnosis of meningitis, myositis and diseases involving the vertebrae and the spinal cord.

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739. Knutsson, F.: The Instability Associated with Disc Degeneration in the Lumbar Spine, Acta radiol. **25**:593-609, 1944.

740. Weens, H. S.: Calcification of the Intervertebral Discs in Childhood, J. Pediat. **26**:178-188 (Feb.) 1945.

Friedman and Read[741] briefly review the subject of orthostatic albuminuria, pointing out that mobilization of masses of young persons has stressed the importance of this condition. They point out that the cause of this condition is still unknown, but it is generally believed that orthostatic albuminuria is due to some disturbance of the renal circulation leading to congestion and venous stasis induced by the upright position. They describe provocative tests of lordosis and the use of these tests in the lordotic type of orthostatic albuminuria. They report a series of 5 orthopedic patients wearing hyperextension body casts for from two to four months or more for all of whom repeated studies of the urine disclosed no albumin and renal function remained unimpaired. Six patients with unrelated medical and surgical conditions were placed in exaggerated lordosis for periods of one to two hours. All these patients had normal urine, and the appearance of albumin could not be induced. The authors believe that these observations confirm the fact that although lordosis plays a role in the pathogenesis of orthostatic albuminuria in susceptible persons it has no influence in producing albumin in normal nonsusceptible persons.

XXI. CONDITIONS INVOLVING THE LOWER PART OF THE BACK

Prepared by

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THE YEAR 1945 produced a considerable number of useful articles on the subject of pain in the lower part of the back and sciatic pain. Intervertebral disk syndromes occupy the predominant place in this literature. The importance of rupture of the intervertebral disk in causing sciatica is firmly established; indeed chief controversy now centers about the question whether almost all sciatica may not be the result of protrusion of the disk. Increased attention is being devoted both to early traumatic lesions of the disk and to degenerative changes secondary to aging and to chronic minor trauma. Concerning detailed diagnostic and therapeutic indications there is as yet little unanimity.

In this review the policy of abstracting the more outstanding articles and of calling attention to the remainder of the year's literature has again been followed.

Pain in the Lower Part of the Back.—An interesting development is the tendency in many quarters to regard early or minor traumatic lesions of the lumbar intervertebral disks as a frequent cause of pain in the lower part of the back in the absence of sciatica.

741. Friedman, A. I., and Read, H. S.: Orthostatic (Lordotic) Albuminuria, Including Studies on Patients in Hyperextension Body Casts, New York State J. Med. **45**:2075-2078 (Oct. 1) 1945.

Key [742] believes that the cause of idiopathic pain in the lower part of the back is practically always intraspinal and in over 90 per cent of the cases a lesion of the intervertebral disk. He states that in most cases the symptoms subside spontaneously or yield to conservative treatment and that in only about 10 per cent is an operation the treatment of choice. Cyriax [743] believes that pressure on the dura mater exerted by a defective annulus fibrosus via the posterior longitudinal ligament is the cause of lumbago; he recommends epidural anesthesia if the symptoms do not subside after a few days of rest in bed. Shapiro [744] also has written on the use of transsacral injection of procaine for pain in the lower part of the back. In the Scandinavian literature, Waldenström [745] has discussed the relationship of lumbago and herniation of the intervertebral disk, and Knutsson [746] has described instability associated with degeneration of the disk in the lumbar part of the spine.

Crisp [747] agrees that pain in the lower part of the back results from damage of the intervertebral disk, believes that early diagnosis can be made and makes a plea for thorough early treatment designed to forestall herniation and sciatica. He states that the cases of pain in the lower part of the back in which if the patient is untreated sciatica will eventually develop are characterized by extreme and persistent spasm of the lumbar portion of the erector spinae muscle with a resultant lumbar lordosis. The patient complains of a continuous aching lumbar pain which is aggravated by movement and coughing and may radiate into the groin. He shows tenderness to deep pressure over the sacroiliac joint and the interspinous ligament of the affected segment; scoliosis is unusual at this stage but as the lesion progresses may be produced by hamstring spasm on the affected side. For these patients the author advises hospitalization and complete rest either in bed or in a plaster jacket. He believes that in early cases the lesion may be a minor tear of the annulus fibrosus without protrusion of the disk and that the spastic

742. Key, J. A.: Intervertebral Disk Lesions Are Most Common Cause of Low Back Pain With or Without Sciatica, Ann. Surg. **121**:534-544 (April) 1945; Intervertebral Disk Lesions Are Most Common Cause of Low Back Pain With or Without Sciatica, Tr. South. S. A. **56**:150-160, 1944.

743. Cyriax, J. A.: Lumbago Mechanism of Dural Pain, Lancet **2**:427-429 (Oct. 6) 1945.

744. Shapiro, L.: Low Back Pain: Treatment by Nerve Block, Indust. Med. **14**:580 (July) 1945.

745. Waldenström, H.: Lumbago and Intervertebral Disk Herniation, Acta chir. Scandinav. **91**:11-16, 1944.

746. Knutsson, F.: Instability Associated with Disk Degeneration in Lumbar Spine, Acta radiol. **25**:593-609, 1944.

747. Crisp, E. J.: Damaged Intervertebral Disk: Early Diagnosis and Treatment, Lancet **2**:422-442 (Oct. 6) 1945.

lordosis is a natural protective mechanism relieving strain and effecting splintage at the level of injury. If the back is protected in a position of lordosis, healing and fibrosis may take the place under the influence of circulation from the posterior longitudinal ligament, together with adaptive shortening of the muscles and ligaments and the production of a permanent protective lordosis. On the other hand, if the diagnosis is not made early and the back remains unprotected, the tear of the annulus gradually increases and leads finally to complete rupture of the fibrocartilage, herniation of the nucleus and the development of sciatica. Crisp thinks that with treatment with a body cast the prognosis for cure is good. Patients with sciatica may be treated by application of a cast with the lumbar part of the spine in kyphosis. After a month or so the herniation is found to be reduced and a cast in the position of lordosis may be used.

A timely warning, however, that the injured intervertebral disk is but one of many causes of backache and sciatica is sounded by Compere.[748] Tippett[749] reviews the symptoms and signs of conditions which cause backache. Samson,[750] editing a symposium from the Hospital of the Sacred Heart in Montreal, stresses the many and varied causes of pain in the lower part of the back. This group of articles,[751] published in the French language, describes the anatomy and physiology of the lower part of the back, the signs and symptoms of cases of pain in the lower part of the back and sciatic pain and the traumatic, mechanical, degenerative, developmental, infectious and arthritic types of syndromes involving the lower part of the back. Included also are discussions of generalized diseases of bone with lumbar manifestations, arthritis of the lumbosacral articular facets and industrial disabilities of the lower part of the back.

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748. Compere, L. A.: Backache with Sciatic Pain, Proc. Interst. Postgrad. M. A. North America (1944), 1945, pp. 184-188.

749. Tippett, G. O.: Diseases of the Spine and Sacro-Iliac Joints, Post-Grad. M. J. **21**:68-72 (Feb.) 1945.

750. Samson, J. E.: Diagnostic differential: Symposium sur le syndrome douloureux lombo-sacré, Union méd. du Canada **74**:1136-1138 (Aug.) 1945.

751. Fortier, M.: Lésions infectieuses vertébrales lombo-sacrées, Union méd. du Canada **74**:1099-1106 (Aug.) 1945; Affections de la sacro-iliaque, ibid. **74**: 1107-1112 (Aug.) 1945. Frenette, U.: Les anomalies congénitales lombo-sacrées, ibid. **74**:1091-1099 (Aug.) 1945. Gariépy, R.: Séméiologie des syndromes douloureux lombo-sacrés, ibid. **74**:1069-1076 (Aug.) 1945. Lepine, E.: Anatomie de la region lombo-sacré: Symposium sur le syndrome douloureux lombo-sacré, ibid. **74**:1051-1057 (Aug.) 1945. Létienne, L.: Syndrome lombo-sacré par tumeurs vertébrales, maladies osseuses généralisées à manifestations vertébrales et ostéoporose d'origine endocrinienne, ibid. **74**:1112-1116 (Aug.) 1945. Potvin, P.: Les déformations mécaniques et statistiques lombo-sacrés, ibid. **74**:1082-1088 (Aug.) 1945; Lésions des tissus mous dans la lombalgie, ibid. **74**: 1088-1091 (Aug.) 1945. Samson, J. E.: Arthrite chronique apophysaire (symposium sur le syndrome douloureux lumbo-sacré), ibid. **74**:1117-1126 (Aug.) 1945.

Hauser [752] believes that inflammation of the lower part of the back resulting from mechanical strain is a much more frequent cause of backache than a slipped intervertebral disk. He stresses the point that pain in the lower part of the back may be produced by physiologic changes in the absence of outstanding structural abnormalities. He applies the term "functional decompensation" to the imbalance between the loads which the back is called on to bear and its capacity to withstand these loads. Factors tending to produce such decompensation are obesity, excessive physical activity, debilitating diseases and poor muscle tone. The influence of inadequate exercise, poor hygienic conditions and improper diet is discussed. The symptoms referable to the back are primarily those of fatigue; pain in the lower extremities is presumably of referred type attributable to inflammation of muscle or joint and the resulting reflex muscle spasm. Irritation over a long period of time may lead to sensory disturbances and impairment of muscle tone. Increase of the normal curvatures of the spine results in poor posture. The physical signs of functional decompensation of the back are faulty posture, decreased muscle tone and a positive straight leg raising sign. Additional changes observed in the acute stage include spasm of the lumbar muscles, decreased lumbar lordosis, tilting of the pelvis and scoliosis.

In a second article Hauser [753] reviews the clinical picture of functional decompensation and recommends the use of a corrective body cast. This is applied with the patient standing in a flexed position in order that when he afterward stands erect the excessive lumbar lordosis and dorsal kyphosis may be corrected.

Methods of care at home and personal conduct designed to relieve the patient with a strained back have been described by Heller.[754]

Fox [755] reports in the neuropsychiatric literature his observations on a series of soldiers with backache, all of whom were first examined by an orthopedist and then referred routinely for psychiatric consultation. Most of the patients exhibited poor posture. They were treated by physical therapy with emphasis on the correction of postural defects. The treatment was thought to be of great value in improving morale as well as posture and backache. The author advisedly points out the

752. Hauser, E. D. W.: Low Back Pain Due to Functional Decompensation of Back, Wisconsin M. J. **44**:869-873 (Sept.) 1945.

753. Hauser, E. D. W.: Corrective Cast for Treatment of Low Back Pain, J. A. M. A. **128**:92-93 (May 12) 1945.

754. Heller, E. P.: Back Saving: Outline of Home Care and Personal Conduct, Indust. Med. **14**:508 (June) 1945.

755. Fox, H. M.: Treatment of Soldiers Complaining of Backache: Some Observations Concerning Posture and Attitude, J. Nerv. & Ment. Dis. **102**:154-164 (Aug.) 1945.

need of cooperation between orthopedist, psychiatrist and physical therapeutist in the treatment of soldiers with backache.

Pain in the lower part of the back ascribed to the herniation of fascial fat is discussed by Herz.[756] He reports 6 operative cases, in only 1 of which the fatty mass had a discernible pedicle. In all cases relief of pain followed excision of the fatty tissue. Microscopically these small masses consisted principally of fat with areas of fibrous tissue, congested blood vessels, edema and focal hemorrhage. In 1 specimen nerve tissue was found. The histologic diagnosis was fibrolipoma. Mylechreest[757] reports his observations on dissections of the back for the study of fat patterns and on 4 patients whose symptoms were completely relieved after the removal of small fatty masses.

An article on estimating disabilities of the back has been contributed by Lewin,[758] and Stark[759] has discussed pain in the lower part of the back in the Army Specialized Training Program.

Osteitis condensans ilii is the subject of an article by Hare and Haggart[760]; they report 23 patients, all of whom were women of childbearing age. This condition, first described in 1926, is characterized clinically by recurrent attacks of pain in the lower part of the back and in the pelvis and roentgenographically by a condensation of iliac bone adjacent to the sacroiliac joint without involvement of the joint space or of the sacrum. For most cases the conservative measures of rest, physical therapy and a support for the lower part of the back constitute adequate treatment. Hare and Haggart describe the differential characteristics which they use in distinguishing osteitis condensans ilii from arthritis of Marie-Strümpell type.

Sciatica.—Increasing emphasis on the ruptured lumbar disk as the cause of most instances of sciatic pain makes it important to remember that other lesions may produce this symptom. The year's articles on sciatica include references to such lesions as well as to therapeutic methods designed primarily for the symptomatic relief of sciatic pain.

Magnuson[761] points out that narrowing of the intervertebral disk space is a frequent occurrence and that little narrowing is required to

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756. Herz, R.: Herniation of Fascial Fat as Cause of Low Back Pain with Relief by Surgery in Six Cases, J. A. M. A. **128**:921-925 (July 28) 1945.

757. Mylechreest, W. H.: An Investigation into the Aetiology and Pathology of Fibrositis of the Back, Ann. Rheumat. Dis. **4**:77-79 (June) 1945.

758. Lewin, P.: Estimation of Back Disability Reduced to Simple Mathematical Formula, Indust. Med. **14**:571 (July) 1945.

759. Stark, L. J.: Low Back Pain in Army Specialized Training Program, Journal-Lancet **65**:223-225 (June) 1945.

760. Hare, H. F., and Haggart, G. E.: Osteitis Condensans Ilii, J. A. M. A. **128**:723-727 (July 7) 1945.

761. Magnuson, P. B.: Intervertebral Disks, Am. J. Surg. **67**:228-236 (Feb.) 1945.

cause compression of a nerve root in its intervertebral foramen. From roentgenographic studies of the spine in flexion and in hyperextension, Capener [762] concludes that the meninges and the cauda equina may be under tension when the back is flexed. He also believes that when the spine is sharply flexed the quadratus lumborum may at times go into spasm to act as an abnormal flexor. Sciatica has been discussed also by Campbell,[763] and its association with pain and deformity of the back has been emphasized by Wardle.[764]

Holmes and Sworn [765] report 3 instances of macroscopic pathologic changes in nerve roots in the absence of protrusion of an intervertebral disk. The clinical picture of these cases was indistinguishable from that of a ruptured intervertebral disk. In 2 instances the root was edematous, and in the third adhesions were present around the root in the spinal canal. Diagnoses of sciatic neuritis were made; the causation was not determined with certainty.

Clavel and Meneault [766] report laminectomy and resection of strangulating adhesions of the dural cul-de-sac. Briggs and Krause [767] discuss the indications, technic and results of intervertebral foraminotomy for the relief of sciatic pain, basing their study on a series of 35 cases. This operative procedure converts the closed canal of the intervertebral foramen into an open trough by removal of the articular processes and facets. The authors feel that the indications for foraminotomy are: (1) failure of simple laminectomy with complete exploration of the accessible nerve root within the neural canal to reveal the impinging mass; (2) complete or considerable collapse of the intervertebral disk space with or without hypertrophic lipping as seen in the roentgenogram, and (3) persistent sciatic pain following a spinal operation with or without fusion. Sufficient bone, ligamentum flavum and capsule are removed to allow visualization of the nerve root along its entire course until it passes into soft tissue. The operation is completed by placing a small piece of muscle tissue over the exposed nerve root and by carrying out spinal fusion. At the 35 operations, the following lesions were found:

762. Capener, N.: Sciatica: Anatomical and Mechanical Study of Lumbo-Sacral Region, Ann. Rheumat. Dis. **4**:29-36 (Dec.) 1944.

763. Campbell, J. F. M.: The Sciatic Syndrome, J. Roy. Nav. M. Serv. **31**: 24-25 (Jan.) 1945.

764. Wardle, E. N.: Sciatic Pain: Its Relation to Pain in the Back and Spinal Deformity, M. Press **213**:197-201 (March 28) 1945.

765. Holmes, J. M., and Sworn, B. R.: Sciatic "Neuritis," Brit. M. J. **2**: 350-351 (Sept. 15) 1945.

766. Clavel, C., and Meneault: Névralgie sciatique gauche: Laminectomie; Résection d'un bride etranglant le cul-de-sac dural, Lyon chir. **37**:114-115, 1941-1942.

767. Briggs, H., and Krause, J.: Intervertebral Formaminotomy for Relief of Sciatic Pain, J. Bone & Joint Surg. **27**:475-478 (July) 1945.

(1) diminution of foraminal space secondary to thinning of the intervertebral disk; (2) hypertrophic lipping of the posterior periphery of the vertebral bodies (this hypertrophy was often cartilaginous and absent in the roentgenogram); (3) herniation of the disk into the intervertebral foraminal space, and (4) impaction of nuclear material within the foramen after migration from a distant point of rupture. The relief of sciatic pain within a follow-up period of from three months to four years was complete in all cases except 3 which the authors consider unsolved diagnostic problems. [ED. NOTE: This percentage of relief is high, especially in view of the fact that 25 per cent of these patients had been subjected previously to spinal fusion with or without removal of a herniated disk and that all had had long intervals of rest, use of a brace and other conservative measures before foraminotomy. As stated by the authors, the follow-up period is too short to allow of conclusive evaluation.]

In foreign literature, Sahlgren and Sjöqvist [768] have discussed myalgic pressure points in sciatica, and Brüel [769] and Vaubel [770] have described the treatment of sciatic pain by injections of procaine hydrochloride. Articles on epidural injection have been published by Galbiati [771] and Decourt.[772]

Intervertebral Disks.—Articles on the intervertebral disk include studies of its pathologic lesions, reviews of the ruptured disk syndrome, contributions to the diagnosis of herniation of the disk and reports on therapeutic indications and results.

In three articles published in the *Journal of Bone and Joint Surgery,* Coventry, Ghormley and Kernohan [773] record the results of their study of the microscopic anatomy and pathology of the intervertebral disk. Specimens from 88 necropsies were examined roentgenographically and microscopically. The first article of this series deals with the anatomy, embryology and physiology of the disk. The second presents a descrip-

768. Sahlgren, E., and Sjöqvist, O.: So-Called Myalgic Pressure Points in Sciatica, Nord. med. (Hygiea) **22**:1141-1142 (June 16) 1944.

769. Brüel, O.: Relief of Pain as Therapeutic Measure: Impletol in Common Painful Conditions, Nord. med. **21**:190-196 (Feb. 4) 1944.

770. Vaubel, E.: Die Injektionsbehandlung der Schmerzzustände im Gebiet des Nervus ischiadicus, Deutsche med. Wchnschr. **70**:28 (Jan. 21) 1944.

771. Galbiati, R.: Contribución al tratamiento de la ciática funicular o neurodocitis por la vitamina B_1 epidural, Semana méd. **2**:630-632 (Sept. 10) 1942.

772. Decourt, J.: Is It Necessary to Renounce Epidural Injections of Iodized Oil (Lipiodol) in the Treatment of Sciatica? Rev. neurol. **75**:192-194 (July-Aug.) 1943.

773. Coventry, M. B.; Ghormley, R. K., and Kernohan, J. W.: Intervertebral Disc: Its Microscopic Anatomy and Pathology; I. Anatomy, Development and Physiology, J. Bone & Joint Surg. **27**:105-112 (Jan.) 1945; II. Changes in the Intervertebral Disc Concomitant with Age, ibid. **27**:233-247 (April) 1945; III. Pathological Changes in the Intervertebral Disc, ibid. **27**:460-474 (July) 1945.

tion of changes in the normal disk in successive decades of life. The third article concerns pathologic changes; these include hypertrophic arthritis, nuclear expansions, ballooned disks, thinned disks, nuclear protrusions, calcification of the nucleus pulposus, infections of the disk and invasion by malignant tumors. The authors point out the difficulty of distinguishing in many cases between degenerative changes which normally accompany the aging process and those which should be termed pathologic. [ED. NOTE: These observations are fundamental to an understanding of intervertebral disk syndromes; they should be studied in detail in the original paper.]

Mooney [774] reviews the pathologic changes which take place in the intervertebral disks with increasing age and the clinical pictures which these changes may produce. He discusses and illustrates the escape of nuclear material into the substance of a vertebral body; he believes that such lesions cause backache which subsides as a bony barrier is formed about the extruded nuclear material. The author contrasts this lesion of limited protrusion of central nuclear material with that occurring in tuberculosis, when the nucleus bursts unopposed through a destroyed cartilaginous plate, leading to complete collapse and destruction of the disk. Mooney believes that Scheuermann's disease is definitely an osteochondritis of the ossific nuclei of the vertebral epiphyseal groove rather than a lesion of the intervertebral disk. Three types of posterior lesion of the disk are described: (1) a simple annular tear with a central nucleus undisturbed and taking no part in the extrusion; (2) an annular tear with a posteriorly situated nucleus which ruptures and adds greatly to the bulk of the extruded tissue, and (3) an annular tear with an intact or practically intact posterior nucleus which protrudes as a glistening mass, lifting up the dural sheath. Mooney also describes the degeneration and thinning of the disk which begin at about the age of 40 years and the posterior nodal protrusions which are localized degenerative changes occurring usually after the age of 50 years and as a rule not causing symptoms. [ED. NOTE: This brief article is of value in calling attention to the variety of lesions to which the intervertebral disk is subject.]

A study of intervertebral spatial changes following extraction of the protruded disk is reported by Graf and Hamby.[775] They introduced a small amount of tantalum powder into the disk sinus in 25 cases. Roentgenographically the sinus appeared either as an elongated slit with an irregular cross section or, less frequently, as a round or oval cavity. Finding that in 1 case the opaque material extended to the

774. Mooney, A. C.: Disc Lesions in Relation to Pain, Brit. J. Radiol. **18**: 153-157 (May) 1945.

775. Graf, C. J., and Hamby, W. B.: Roentgenographic Demonstration by Tantalum Power of Sinuses Resulting from Extraction of Intervertebral Disc Protrusions, Am. J. Roentgenol. **53**:157-160 (Feb.) 1945.

anterior edge of the vertebral body, the authors warn that curettage of the disk must be carried out cautiously in order to avoid penetration of the annulus. Roentgenograms made after several months of normal activity following operation showed no significant alterations. A patient who showed signs of a contralateral lesion postoperatively was reexplored. Histologic observations suggested only mild reaction about the tantalum.

Current conceptions of the clinical syndrome of the ruptured intervertebral disk are presented in a number of articles.[776] The association of protrusion of the disk with spondylolisthesis is discussed by Meyerding.[777] Massive extrusion of a lumbar disk is described by Ver Brugghen.[778] He calls attention to the serious complications which may occur when a ruptured disk is inadequately treated. The extrusion of a large part of a disk may so compress the cauda equina as to cause weakness of a lower extremity with disturbance of urinary function or even to produce a transverse lesion of the cauda equina with paraplegia and incontinence of bladder and rectum. Lesions of this type are sometimes not diagnosed promptly despite the fact that the patient's condition is serious and constitutes a neurosurgical emergency. Ver Brugghen believes that massive extrusions are seen perhaps once in 300 cases of herniated disk. Most of his 9 patients gave a "cogwheel" history in which the picture developed in successive short acute episodes over a considerable period. He discusses the differential diagnosis in 8 cases in which operation was performed. The results were excellent in 1 case, good in 1 and fair in 6. One patient continued incontinent after three and one-half years, and another had a persistent paraplegia and was confined to a wheel chair two and one-half years after operation.

The year's articles on the diagnosis of protrusions of the intervertebral disk include clinical analyses and statistical reports of myelographic observations. Munro[779] discusses the characteristic symptoms and signs. In a review of 177 laminectomies for suspected lesions of the

776. Bradford, F. K.: El problema del disco intervertebral en la marina de guerra, Rev. radiol. y fisioterap. **12**:37-44 (May-June) 1945. Larson, C. B.: Medical Progress: Orthopaedic Surgery; Problem of Intervertebral Disk, New England J. Med. **232**:137-139 (Feb. 1) 1945. Swett, P. P.: A Note on Sciatica, Backache and Intervertebral Disks, Connecticut M. J. **9**:701-702 (Sept.) 1945. Walker, E.: Intervertebral Disc Lesions: General Discussion and Consideration of Treatment in Military Service, South. M. J. **38**:832-834 (Dec.) 1945. Young, J. H.: Intervertebral Disk Disease: New Syndromes and New Concepts, M. J. Australia **2**:234-245 (Aug. 25) 1945.

777. Meyerding, H. W.: Protusión de los discos intervertebrales en los casos de espondilolistesis, Medicina, México **25**:342-349 (Aug. 25) 1945.

778. Ver Brugghen, A.: Massive Extrusions of Lumbar Intervertebral Discs, Surg., Gynec. & Obst. **81**:269-277 (Sept.) 1945.

779. Munro, D.: Diagnosis of Posterior Herniation of Lumbar Intervertebral Disks, New England J. Med. **232**:149-160 (Feb. 8) 1945.

disks, Burns and Young [780] describe a "tension test" which they found useful in differential diagnosis. They raise the patient's affected leg with the knee straight until pain is produced, then flex the knee just enough to relieve the pain; persistence of pain suggests that there is a lesion of the hip. The head is then flexed on the chest; return of pain indicates a lesion of the back. Further flexion of the knee will then relieve the pain of an intraspinal lesion by releasing tension on the meninges; continued pain is thought to indicate a lesion outside of the spinal canal.

Fincher,[781] in a discussion of the neurosurgical aspects of lumbar and sciatic pain with especial reference to differential diagnosis, points out that the outstanding diagnostic groups consist of the protrusions of the intervertebral disk, the tumors of the spinal cord and the compensation neuroses. He describes the differential diagnosis of each of these entities with reference to the history, physical examination and roentgenograms and myelograms.

Norlen [782] has published a detailed analysis of the value of neurologic symptoms in localizing herniations of the lumbar disk. In a study of 37 verified cases of rupture of the disk published in 1942 but not available previously for review, Friberg [783] found an average concentration of total proteins of 60 mg. per hundred cubic centimeters, a low globulin-albumin quotient and little or no increase of cells in the cerebrospinal fluid.

Four papers on myelography are in agreement in pointing out the diagnostic value of myelograms and in advocating "pantopaque" (a mixture of ethyl esters of isomeric iodophenyl undecylic acids) as the most desirable contrast medium. Echlin, Ivie and Fine [784] think that "pantopaque" has made myelography a simple, justifiable, and reasonably accurate procedure. Peacher and Robertson,[785] in a well documented study, found the accuracy of myelographic diagnosis to be 96.7

780. Burns, B. H., and Young, R. H.: Protrusion of Intervertebral Disk, Lancet **2**:424-427 (Oct. 6) 1945.

781. Fincher, E. F.: Neurosurgical Aspects of Lumbar and Sciatic Pain, J. M. A. Georgia **34**:149-154 (Aug.) 1945.

782. Norlen, G.: On Value of Neurological Symptoms in Sciatica for Localization of Lumbar Disc Herniation: Contribution to Problem of Surgical Treatment of Sciatica, Acta chir. Scandinav. (supp. 95) **91**:1-96, 1944.

783. Friberg, S.: Ueber Untersuchungen der Eiweisskonzentration im Liquor bei lumbalen Bandscheibenprolapsen, Acta chir. Scandinav. **87**:128-137, 1942.

784. Echlin, F. A.; Ivie, J. M., and Fine, A.: Pantopaque Myelography as Aid in Pre-Operative Diagnosis of Protruded Intervertebral Disks: Preliminary Report, Surg., Gynec. & Obst. **80**:257-260 (March) 1945.

785. Peacher, W. G., and Robertson, R. C. L.: Pantopaque Myelography: Results; Comparison of Contrast Media and Spinal Fluid Reaction, J. Neurosurg. **2**:220-231 (May) 1945.

per cent. Soule, Gross and Irving [786] think myelography should be done in nearly every case of pain in the lower part of the back with sciatic radiation when operation is contemplated. Arbuckle, Shelden and Pudenz [787] recommend routine "pantopaque" myelography as an aid in the diagnosis and localization of protruded disks and in ruling out tumors of the spinal cord, the meninges and the cauda equina.

The treatment of the patient with a ruptured disk has been outlined by Key.[788] Noting that the severity of the symptoms and signs varies greatly in different patients and at different times in the same patient, he divides the patients therapeutically into three categories: ambulant, bed and operative groups. The ambulant patients are treated by support of the lower part of the back, manipulation, stretching of the lower part of the back, correction of body mechanics by exercise, a hard flat bed, administration of vitamin B, weight correction, administration of salicylates and change of occupation if necessary. Bed patients, whose symptoms are so severe that they are unable to carry on their daily routine, are treated in similar fashion and returned gradually to activity. If conservative treatment proves unsatisfactory, if the patient is unrelieved or is intolerant of his symptoms and demands relief by surgical treatment or if he has a long history of disability which has not responded to treatment elsewhere, operative treatment is considered. Key thinks that the intact spine should not be fused after the removal of a protruding intervertebral disk and reserves fusion for those patients with long-continued chronic backache in whom the roentgenograms reveal a collapsed disk and in whom no pressure on the nerve roots is found and relieved at operation. Key does not use bone chips over the open spinal canal after the ligamentum flavum has been removed but reenforces the fusion with a notched plate graft taken from the posterior portion of the wing of the ilium. He states that the results of operation for lesions of the intervertebral disks have not been so uniformly successful in his hands as he would wish and analyzes briefly the probable causes of failure. He believes that pain in the lower part of the back with or without sciatica should be treated conservatively and that operative removal of the disk should be reserved for those patients who do not respond to conservative therapy. He considers the removal of ruptured intervertebral disks a sound procedure if the cases are properly selected.

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786. Soule, A. B., Jr.; Gross, S. W., and Irving, J. G.: Myelography by Use of Pantopaque in Diagnosis of Herniation of Intervertebral Discs, Am. J. Roentgenol. **53**:319-340 (April) 1945.

787. Arbuckle, R. K.; Shelden, C. H., and Pudenz, R. H.: Pantopaque Myelography: Correlation of Roentgenologic and Neurologic Findings, Radiology **45**:356-369 (Oct.) 1945.

788. Key, J. A.: Conservative and Operative Treatment of Lesions of Intervertebral Discs in Low Back, Surgery **17**:291-303 (Feb.) 1945.

Kirstein [789] reports a follow-up study of 49 patients who had sciatic pain and roentgenographic evidence of a space-restricting lesion in the spinal canal. [ED. NOTE: Kirstein's statistics, which suggest more favorable results in the 25 patients who were treated by operation, are of little value because of the too brief follow-up period of from one-half to three years.]

A study of the end results of the combined operation of excision of the disk herniation and lumbosacral arthrodesis was published by Ghormley, Love and Young [790] in 1943 but has not been reviewed in previous editions of the "Progress in Orthopedic Surgery." Of a series of 72 cases, the results after a follow-up period of from one to four years were good in 46 patients, fair in 18 and poor in 8. In addition to the herniated disk certain of these patients had spondylolisthesis, spondylolysis, sacralization, osteoarthritis, sacroiliac arthritis or multiple, recurrent or thinned disks.

Marble and Bishop [791] have analyzed the results of operations on intervertebral disks in a series of 92 industrial cases and have compared them with the results in nonindustrial cases. The proportion of favorable results, less than 50 per cent, is appreciably lower in the industrial cases. The authors point out the greatly increased financial outlay required for operative treatment and for compensation of the patient with an unfavorable outcome following operation. As would be expected, the statistics show that supplementary fusion of the lower part of the back is a less desirable procedure in industrial cases than in nonindustrial. [ED. NOTE: This may be particularly true when the results are evaluated over a relatively short follow-up period.]

Poppen [792] reviews a series of 400 cases of herniated intervertebral disk verified by operation. He believes that the patient who has sciatica and minor back difficulties and whose roentgenograms show no changes in the bone should only have the disk removed; he thinks that the patient who has predominant pain in the back, definitely abnormal facets and instability of the back and who must do hard manual labor should have removal of the degenerated cartilage and fusion. Complete relief of pain in the back and sciatic pain was obtained in 65 per cent of the cases and complete relief of sciatica in 90 per cent. Five per cent of the patients were unrelieved.

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789. Kirstein, L.: An After-Examination of Operated and Non-Operated Cases with Clinical Symptoms of Herniated Disc, Acta med. Scandinav. **120**: 93-106, 1945.

790. Ghormley, R. K.; Love, J. G., and Young, H. H.: Combined Operation in Low Back and Sciatic Pain, Am. Acad. Orthop. Surgeons, Lect., 1943, pp. 120-125.

791. Marble, H. C., and Bishop, W. A.: Intervertebral Disc Injury: Analysis from Industrial Standpoint, J. Indust. Hyg. & Toxicol. **27**:103-109 (April) 1945.

792. Poppen, J. L.: Herniated Intervertebral Disk: Analysis of Four Hundred Verified Cases, New England J. Med. **232**:211-215 (Feb. 22) 1945.

Poppen also calls attention to 6 patients who had massive rupture of a disk attended by sudden complete paraplegia. In 2 of these cases paralysis developed immediately after manipulation by osteopaths and in 2 it was apparent on awakening from anesthesia after manipulation by a competent orthopedist. Many weeks or months elapsed before complete function returned. [ED. NOTE: Although this complication does not occur frequently, its gravity makes routine manipulation inadvisable.] A rare complication of operative removal of the disk, an arteriovenous fistula between the right common iliac artery and the inferior vena cava, is reported by Linton and White.[793]

Spondylolisthesis.—The number of articles on spondylolisthesis suggests an increased interest in this subject. Buus [794] published in 1943 a detailed discussion of spondylolysis and spondylolisthesis which has not been available for review in previous editions of the "Progress in Orthopedic Surgery." Of 27 reported cases, 20 were observed for from one to twenty-four years. No relationship between trauma and the degree of slipping was demonstrable. The spinal canal was found to be of normal width in cases of mild slipping and only slightly narrowed in the presence of severe slipping. Symptoms, signs and methods of treatment were reviewed. More recently Walker,[795] finding 52 cases of spondylolisthesis in 12,000 Canadian recruits, has discussed the subject with particular reference to the physical signs.

Meschan [796] describes a method of measuring the degree of spondylolisthesis by means of lines drawn on the lateral roentgenogram. Using this method for comparison of the roentgenographic findings with the patient in various positions, he was able to demonstrate instability at the level of the spondylolisthesis in 7 of 41 patients.

Meyerding [777] has published in the Mexican literature an article on the protrusion of intervertebral disks in spondylolisthesis. The belief of Dandy [797] that the symptoms encountered in spondylolisthesis are the results of lesions in disks at other levels of the spine is not shared by most orthopedic surgeons.

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793. Linton, R. R., and White, P. D.: Arteriovenous Fistula Between the Right Common Iliac Artery and the Inferior Vena Cava, Arch. Surg. **50**:6-13 (Jan.) 1945.

794. Buus, C. E. P.: On Spondylolysis and Spondylolisthesis, Acta orthop. Scandinav. **14**:1-96, 1943.

795. Walker, J. A. L.: Physical Signs of Spondylolisthesis, J. Canad. M. Serv. **2**:478-482 (May) 1945.

796. Meschan, I.: Spondylolisthesis: A Commentary on Etiology and an Improved Method of Roentgenographic Mensuration and Detection of Instability, Am. J. Roentgenol. **53**:230-243 (March) 1945.

797. Dandy, W. E.: Treatment of Spondylolisthesis, J. A. M. A. **127**:137-139 (Jan. 20) 1945.

Hambly [798] describes a case of extreme reversed lumbar spondylolisthesis attended by spastic paraplegia. He states that this congenital abnormality is exceedingly rare. Lombard [799] has written on congenital lumbosacral luxation.

For the treatment of spondylolisthesis and laminal defects, Bosworth [800] advocates the use of a "clothespin" or H-shaped graft taken from the ilium or the tibia and mortised about the spinous processes at each end of the fusion area. He states that such grafts should always be supplemented by strips of iliac bone.

Congenital Lumbosacral Anomalies.—Fischer and Vandemark [801] present the case histories and roentgenograms of 2 patients who had sagittal cleft or butterfly vertebrae, a rare congenital anomaly which may affect the lumbar part of the spine. This division of a vertebral body into lateral halves by an intervening sagittal cleft was described one hundred years ago by von Rokitansky. Vertebrae with saggital clefts have been associated with other malformations of vertebrae and ribs. Pain may or may not be present in the back. Treatment consisting of limitation of activity, avoidance of heavy lifting and the use of a back support may be indicated.

McMaster [802] reports a case of unilateral hypoplasia of the lumbosacral articular processes and associated neural arch of the fifth lumbar vertebra. The patient's pain in the lower part of the back and the thigh was on the side opposite that of the anomaly. McMaster suggests that this patient may have had two primary centers of ossification for the affected half of his fifth lumbar neural arch and that of these the center for the posterior portion may have been hypoplastic.

An operation for stabilization of the asymmetrically sacralized lumbosacral junction has been described by Elo.[803]

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798. Hambly, E. H. T.: Reverse Spondylolisthesis, Brit. J. Surg. **32**:536 (April) 1945.

799. Lombard, P.: Le spondylolisthésis: Luxation congénital lombo sacrée, l'hypothétique glissement de la 5e lombaire, Afrique franç. chir. **1**:62-63 (March) 1943.

800. Bosworth, D. M.: Clothespin Graft of the Spine for Spondylolisthesis and Laminal Defects, Am. J. Surg. **67**:61-67 (Jan.) 1945.

801. Fischer, F. J., and Vandemark, R. E.: Sagittal Cleft (Butterfly) Vertebra, J. Bone & Joint Surg. **27**:695-698 (Oct.) 1945.

802. McMaster, P. E.: Unilateral Hypoplasia of Lumbosacral Articular Processes: Case Report, J. Bone & Joint Surg. **27**:683-686 (Oct.) 1945.

803. Elo, R.: Stabilizing Operation for Asymmetrical Sacralization, Acta chir. Scandinav. **92**:86-98, 1945.

(To Be Continued)